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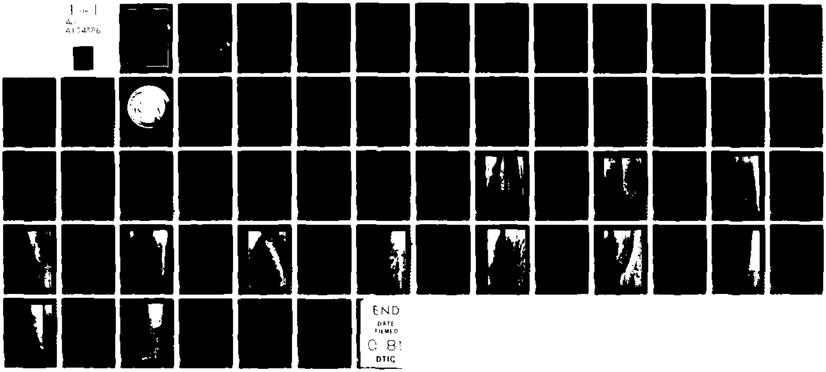

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RECOVERY FROM GEOGRAPHIC DISORIENTATION BY MEANS OF BRIEF UNMASKING MANEUVERS DURING SIMULATED NAP-OF-THE-EARTH FLIGHT

Submitted to:

DEPARTMENT OF THE ARMY
U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
Field Unit (PERI-OA)
Fort Rucker, Alabama

and

ADVANCED SYSTEMS DIVISION
U.S. ARMY AVIONICS R&D ACTIVITY
Fort Monmouth, New Jersey

February 1980

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An experimental study was conducted to determine the ability of experienced aviators to recover from geographic disorientation by means of brief unmasking maneuvers during simulated nap-of-the-earth flight. The simulation was made visually realistic by the use of a special lens and screen system that provided a 360° field of view, completely surrounding the aviators. Photographic imagery was obtained at 12 geographic sites, and represented a broad range of terrain types. The lens system also projected compass information at the top edge of the screen. Aviators attempted to identify the

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The results of the study indicated that recovery from geographic disorientation is characterized by sudden insights rather than gradual improvements in position-finding. Insight, as defined in the study, occurred in 40% of the cases. Insightful position estimates averaged about 250 meters from the correct site; non-insightful estimates averaged about 1700 meters from the correct site and did not improve with additional exposures of the photograph. Insights were more likely to be achieved at sites including cultural features in the field of view, if these features were depicted on the map. Sites that demanded interpretation of landform contour for re-orientation were associated with the lowest frequency of insights.

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Mr. Gene Kelley, Staff Scientist, Anacapa Sciences, Inc., who directed and coordinated the field effort in acquiring appropriate photographic imagery, and acted as consultant on optical optimization of the SURNOT.

Mr. Wiley Dykes, Physical Scientist, Naval Training Equipment Center, who provided the SURNOT device for the experiment, directed the assembly and calibration of the device, and participated in the collection of photographic imagery.

Mr. John Dillard, Physical Scientist Technician, Naval Training Equipment Center, who collaborated in the acquisition of photographic imagery and in the testing of the SURNOT optical system.

ABSTRACT

An experimental study was conducted to determine the ability of experienced aviators to recover from geographic disorientation by means of brief unmasking maneuvers during simulated nap-of-the-earth flight. The simulation was made visually realistic by the use of a special lens and screen system that provided a 360° field of view, completely surrounding the aviators. Photographic imagery was obtained at 12 geographic sites, and represented a broad range of terrain types. The lens system also projected compass information at the top edge of the screen. Aviators attempted to identify the correct position of each site on standard 1:50,000-scale maps of the areas. Four successive brief exposures of each site were presented, simulating the unmasking maneuvers. Twenty-eight experienced pilots participated in the study.

The results of the study indicated that recovery from geographic disorientation is characterized by sudden insights rather than gradual improvements in position-finding. Insight, as defined in the study, occurred in 40% of the cases. Insightful position estimates averaged about 250 meters from the correct site; non-insightful estimates averaged about 1700 meters from the correct site and did not improve with additional exposures of the photograph. Insights were more likely to be achieved at sites including cultural features in the field of view, if these features were depicted on the map. Sites that demanded interpretation of landform contour for re-orientation were associated with the lowest frequency of insights.

TABLE OF CONTENTS

CHAPTER		Page
I	INTRODUCTION	1
	Background	1
	Previous NOE Navigation Research	3
	Objectives of the Study	4
II	METHOD	5
	Apparatus	5
	Task	8
	Procedure	8
	Participants	9
III	RESULTS	11
	Averaged Performance	11
	Insightful Performance	12
	Effect of Experience	21
IV	CONCLUSIONS	23
	Interpretation of Findings	23
	Summary of Findings	26
APPENDIX		
A	GRAPHIC SUMMARY OF EXPERIMENTAL DATA	27
B	ADDITIONAL DATA ON DISORIENTATION	53

LIST OF FIGURES AND TABLES

FIGURE		Page
1	The Surface Navigation and Orientation Trainer.	5
2	Photograph from the end of Daytona Beach Municipal Pier obtained via the SURNOT lens (transparency enlarged 2X).	7
3	The area of uncertainty for Site 1 (indicated by the enclosing line)	8
4	Average error over all 12 sites for Trials 1 through 4 of the experiment	12
5	Average error over all 4 trials for the 12 sites, ranked by error magnitude	13
6	Average error over all 12 sites on Trial 4, for each of the 28 pilots, ranked by error magnitude. . . .	14
7	The average error before and after insight in those cases in which insight was achieved. Cases in which insight was not achieved are shown by Trial 1 through 4 for comparison.	17
8	Average error on Trial 4 for the 12 sites, ranked by error magnitude, and averages for the insightful and non-insightful cases separately	18
9	Pilots ranked by average performance on Trial 4 over all 12 sites, and averages for their insight and non-insight cases	20

TABLE		
1	DISTRIBUTION OF INSIGHTS ACROSS THE FOUR TRIALS OF THE EXPERIMENT.	15
2	PEARSON PRODUCT MOMENT CORRELATIONS BETWEEN PILOTS' PERFORMANCE ON THE EXPERIMENTAL TASK, AND THEIR EXPERIENCE AND SELF-RATINGS	21

CHAPTER I
INTRODUCTION

This report describes a study undertaken to evaluate the ability of Army aviators to recover from geographic disorientation encountered during nap-of-the-earth (NOE) flight. The study was conducted under Contract DAHC19-78-C-0012, Modification No. P00003 for the U.S. Army Research Institute for the Behavioral and Social Sciences and for the Advanced Systems Division of the U.S. Army Avionics Research and Development Activity.

BACKGROUND

Navigation during NOE flight is a formidable task, even under the best of conditions. NOE flight is flight as close to the earth's surface as vegetation and obstacles will permit; it involves varying course, airspeed and altitude to take maximum advantage of the cover and concealment offered by terrain, vegetation, and man-made features. Navigation is mainly by pilotage, involving map interpretation and terrain analysis, because continued variation of course and speed severely limits the utility of dead-reckoning navigation techniques and because radio navigation aids are not effective at NOE altitudes.

Correlation of features seen on the map with those present in the terrain is made exceedingly difficult by the aviator's limited view of the terrain from NOE altitudes. The same features that mask the enemy's view of the helicopter also serve to mask the aviator's view of navigational checkpoints. The difficulty of maintaining geographic orientation is further increased when visibility is degraded by darkness or atmospheric attenuation, when the aviator is unfamiliar with the terrain, or when unforeseen events, such as hostile fire, distract the aviator from the navigation task. Given these difficulties, it is logical to expect that temporary spatial disorientation during NOE flight will be a relatively common event.

The standard technique employed for recovering from geographic disorientation is that of returning to the point where the aviator was last certain of his position. This technique may not always be applicable for one or more of the following reasons:

- Enemy activity may preclude returning by the same path.
- The weaving and devious flight route may be impossible to retrace.
- Special mission-timing requirements may not permit a return to the last point of certain orientation.
- A low fuel state or aircraft emergency may prevent the aviator from retracing the flight path.

When one or more of these conditions prevail, the aviator may elect to continue the flight in hope of encountering an identifiable topographic feature or to hold his position until he becomes re-oriented through map interpretation and terrain analysis. In order to obtain sufficient information regarding his surroundings, the aviator may choose to briefly unmask, or "pop up," to perform a visual search of the terrain. The aircraft should never remain unmasked for more than 10 seconds in the high threat environment, and should never exceed an altitude that provides the aviator with a sufficient view of the surrounding terrain. Multiple pop-up maneuvers may be performed if the aircraft is moved to a new position for each maneuver.

There is little doubt that the pop-up maneuver constitutes the most demanding situation for the conduct of re-orientation by map interpretation and terrain analysis. Although reasonable periods may be devoted to map study prior to unmasking, a 10-second limit on time available for terrain analysis requires that the aviator exercise his perceptual and cognitive capabilities to the utmost. The accuracy with which the aviator can determine his position under these circumstances has never before been studied, and the determination of this accuracy was the central goal of the experiment described in this report.

PREVIOUS NOE NAVIGATION RESEARCH

In a prior study[1], the authors experimentally evaluated the ability of NOE aviators to navigate using only terrain relief. Computer-generated maps were used that were printed with contour lines only--no cultural, hydrographic, or vegetation information was present on the maps. The pilots who participated in the experiment viewed a 16-mm motion picture of an NOE flight path at Fort Huachuca, Arizona, and marked the aircraft's exact position on the map at 12 points in the film. The participants were given the correct grid coordinates after each point was marked to assure that they were re-oriented for the beginning of each of the 12 flight segments. Flight segment headings, durations, and ground speeds were varied to deter dead-reckoning solutions. The average error in position identification was approximately 500 meters. Performances were best when navigating near extremely obvious terrain features, or when dead reckoning was possible. When surrounding terrain was not unmistakable, disorientation often occurred and errors ranged out to 5000 meters, although a few aviators were able to perform consistently well.

The experiment described above was primarily concerned with navigation by terrain relief and was structured to test that ability. Recovery from disorientation will depend heavily on analysis of relief, but many other techniques will be employed as they are applicable.

Because all possible techniques would be used, it was clear that a study of recovery from disorientation should be more realistic than the prior study. Specificially, it should include the following conditions:

- The use of actual topographic maps with all types of features depicted--cultural, hydrographic, and vegetation features as well as terrain relief.
- An unrestricted field of view in order to take maximum advantage of surrounding features--at least 180°, or even 360°, if possible.

[1]Rogers, S. P. & Cross, K. D. *Accuracy of geographic orientation during nap-of-the-earth flight as a function of topographic map contour-line interval.* Santa Barbara, California: Anacapa Sciences, Inc., December, 1978.

- A method of determining magnetic azimuths to the features detected in the terrain so that position finding by resection could be performed.

- A representative sample of terrain types varying in elevation range and numbers of cultural, hydrographic, and vegetation features.

These are exceedingly stringent conditions for the conduct of a controlled experiment. The manner by which they were achieved and the results of the experiment are the topics of the subsequent chapters of this report.

OBJECTIVES OF THE STUDY

The general objective of this project was to examine the performances of experienced NOE aviators attempting to recover from temporary geographic disorientation. The specific objectives were to:

- Determine the average error in position identification when attempted during a brief unmasking maneuver.

- Determine the improvement in position identification achieved with successive unmasking maueuvers.

- Assess the variation in performance attributable to different types of terrain and numbers of features.

- Gather ancillary data pertaining to aviators' actual experiences with geographic orientation.

CHAPTER II
METHOD

The experiment was performed through the use of a unique device that provided photographic terrain imagery completely surrounding the participants. This apparatus, and the experimental task, procedure, and participants are discussed in detail below.

APPARATUS

Transparencies of selected terrain were projected by a prototype device developed by the Naval Training and Equipment Center (NTEC). This device, designated the Surface Navigation and Orientation Trainer (SURNOT) was designed to provide a 360° projected display from photographic imagery of actual terrain. The effect is achieved through the use of the special lens both for the acquisition and for the projection of the imagery. The projection screen is configured as a section of a sphere, forming a surface 360° around the viewer and 42° in height. The screen employed in the experiment was approximately 25 feet in diameter and 11 feet in height. Figure 1 shows the SURNOT screen and projection system.

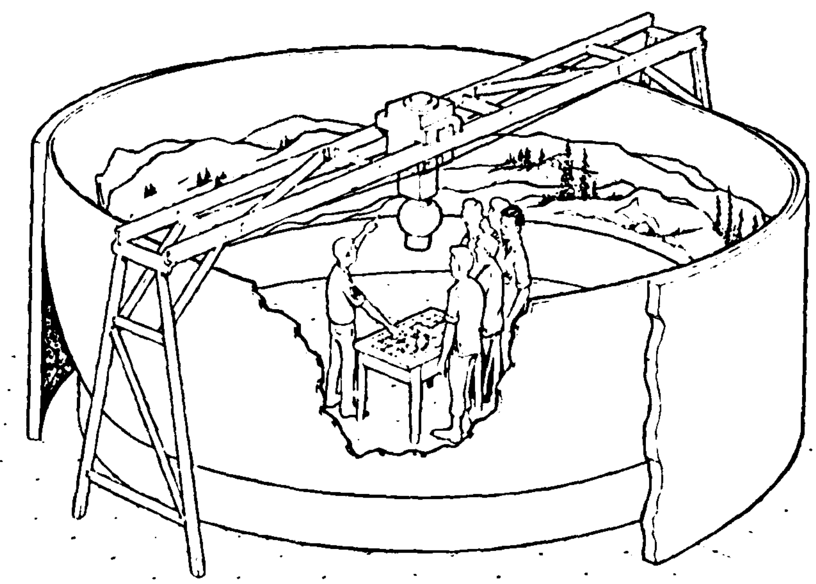


Figure 1. The Surface Navigation and Orientation Trainer.

The SURNOT system employs a donut-shaped image on a 4"x5" film sheet as shown in Figure 2. When this image is projected through the lens onto the spherical screen, the distortion is removed. Measurements of the SURNOT optical system resolution have ranged up to 214 lines/mm. Losses at the screen surface reduce resolution to approximately 110 lines/mm. In order not to degrade this resolution, special aerial color film (Kodak SO305), having a measured resolution of 315 lines/mm, was used for the transparencies.

Imagery for the experiment was obtained by transporting the SURNOT lens to Fort Knox, Kentucky, and a series of areas in California. Imagery was acquired for a broad range of terrain relief--mountainous terrain, steep hills, low hills, and relatively flat terrain--and a diverse selection of hydrographic, vegetation, and cultural features. Samples of imagery from these areas are shown in Appendix A.

The photographs were taken in areas for which standard 1:50,000 scale maps were available. These maps were prepared for experimental use by mounting them on heavy matte board, covering them with an acetate film, and marking them to indicate the "area of uncertainty." The area of uncertainty was a zone that included the site from which the photograph was obtained as well as several square kilometers of adjacent terrain. A typical area of uncertainty is shown in Figure 3. The area of uncertainty served to limit the participants' map study to a reasonable area of the map. The size and shape of the areas of uncertainty were selected by the experimenters on the basis of prior research dealing with geographic disorientation, and the likely range of error encountered in various terrain types. The size of the areas of uncertainty averaged about 10 square kilometers and ranged from approximately 5 to 20 square kilometers.

A shadow-casting device marked with compass directions was mounted surrounding the upper margin of the SURNOT lens. Thus, azimuth information was presented around the top of the circular screen to facilitate resection for position-finding. The device was graduated in 10° increments and labeled every 30°.

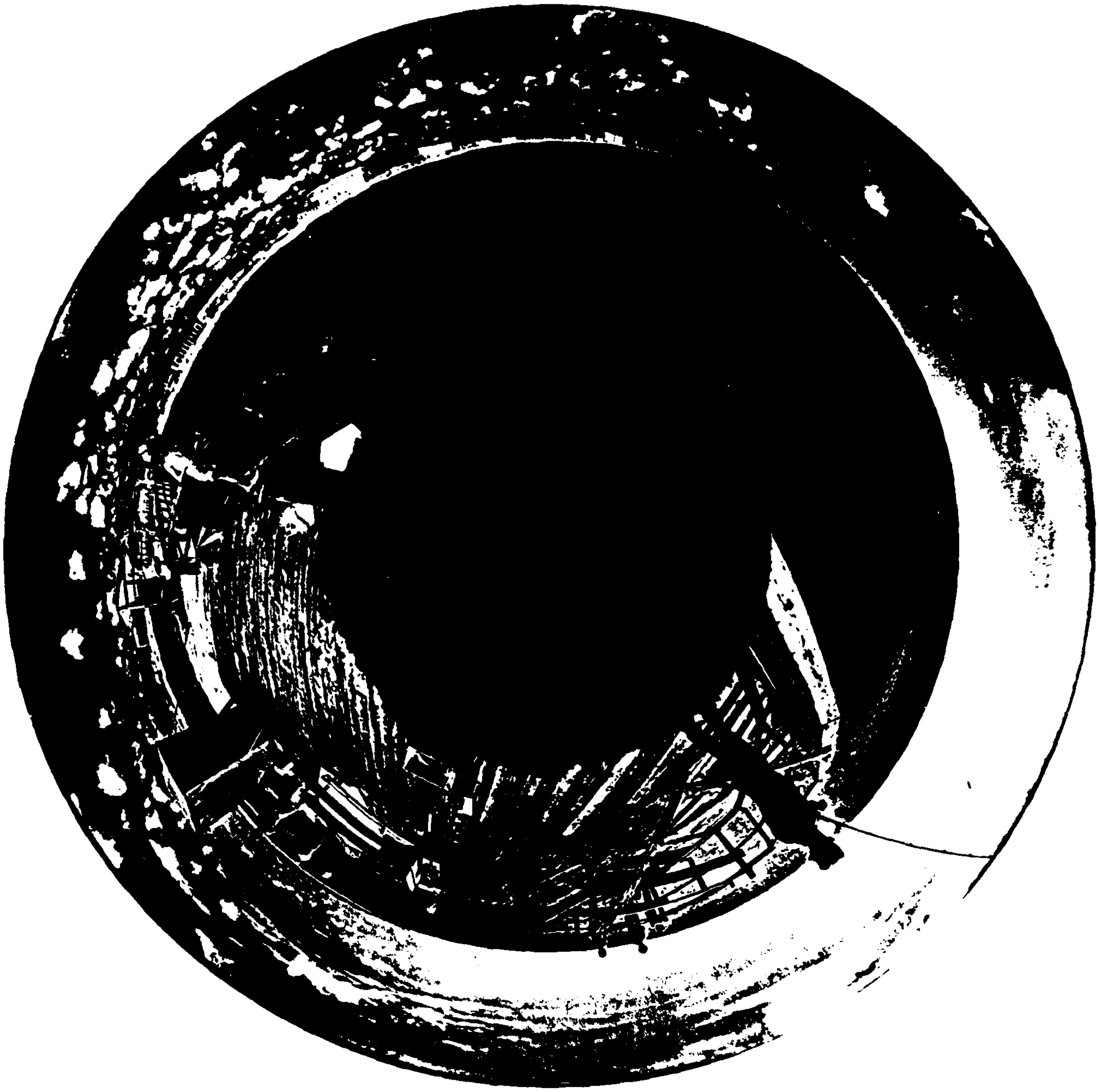


Figure 2. Photograph from the end of Daytona Beach Municipal Pier obtained via the SURNOT lens (transparency enlarged 2X).

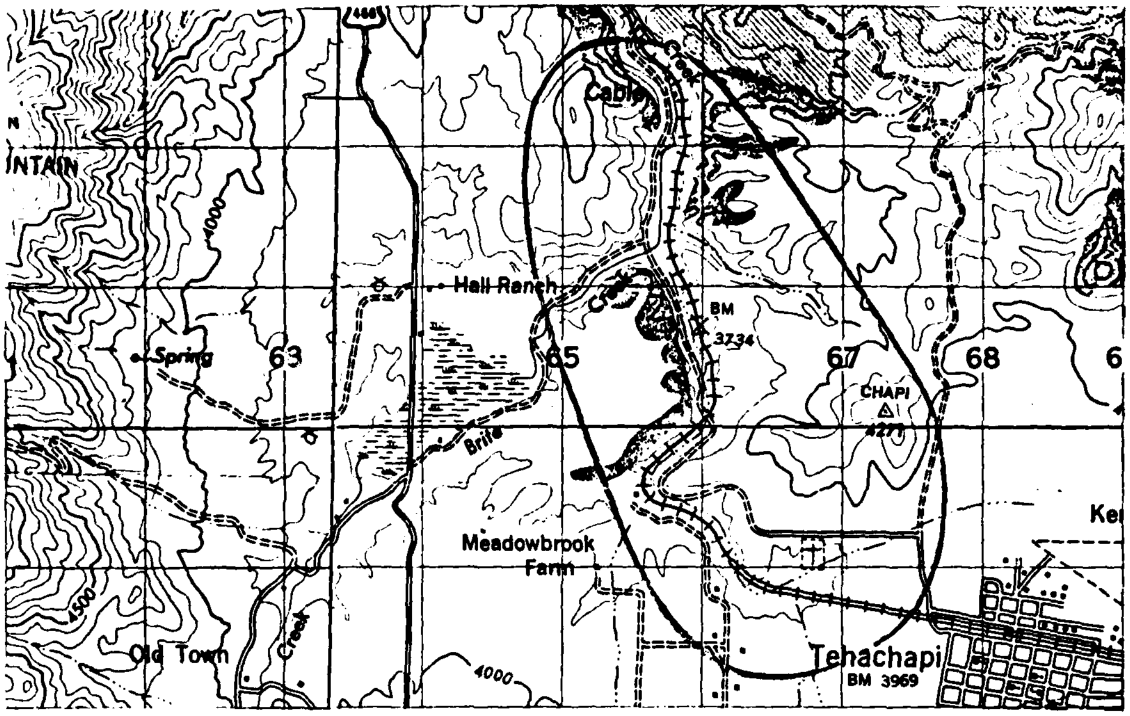


Figure 3. The area of uncertainty for Site 1 (indicated by the enclosing line).

TASK

Participants were requested to study each map and the photographic imagery surrounding them and to determine the position on the map from which each photograph was taken. Each photograph was presented four times and on each of these trials the participants marked the mapsheets to indicate their best estimate of the correct position.

PROCEDURE

The pilots who participated in the experiment were seated on revolving stools near the center of the SURNOT enclosure. No more than six pilots participated during any experimental session. The pilots were requested to complete a short questionnaire pertaining to their aviation background and their most recent experience of temporary geographic disorientation.[2] Pilots were then issued marking pens, a sample mapsheet,

[2]A summary of these data is provided in Appendix B.

and combination penlight/magnifying glasses. The purpose of the experiment and features of the SURNOT were described to the subjects and the instructions for the experiment were read. The subsequent sequence of events for each of the 12 sites was as follows:

1.		Distribution of the mapsheets
2.		30 seconds of map study
3.	(TRIAL 1)	10 second photograph presentation
4.		30 seconds of map study
5.	(TRIAL 2)	10 second photograph presentation
6.		30 seconds of map study
7.	(TRIAL 3)	10 second photograph presentation
8.		30 seconds of map study
9.	(TRIAL 4)	60 second photograph presentation
10.		Collection of the mapsheets

During Trial 4 the 360° photograph was presented for 60 seconds, rather than 10 seconds as in the preceding trials. The 60-second presentation simulated the case of dismounting from the helicopter and approaching a vantage point on foot for a longer period of terrain study than that possible by means of an unmasking maneuver. At the end of each trial, the pilots marked the position on the map from which they estimated the photograph had been taken. The marks were made in the form of an X and labeled 1, 2, 3, or 4, indicating the trial number.

PARTICIPANTS

Twenty-eight experienced helicopter pilots from Lowe Field and Hanchey Field at Fort Rucker, Alabama, participated in the experiment. Their average number of helicopter flight hours was 2,338 (range: 900-5200 hours) and their average number of NOE flight hours was 420 (range: 25-1500 hours).

CHAPTER III
RESULTS

Pilot performance was scored by measuring the distance between the correct map location of each site, and the map locations indicated by the participant on each of the four trials. The results are discussed in two ways: first, as simple averages for the entire group of pilots; and second, as two separate types of performance--insightful and non-insightful. In addition, the correlations between performance and pilot experience are described.

AVERAGED PERFORMANCE

The results described in this subsection pertain to averaged scores for each of the 12 sites, for each of the 28 pilots, and for each of the four trials. These averages seem to lead to inferences that (a) some sites were very much more difficult than others; (b) some pilots were consistently very much better at this task than others, and (c) error in this *orientation* task was gradually reduced with each succeeding trial. In fact, subsequent analyses showed clearly that while the first inference is true, the second is at best a half-truth, and the third inference is completely erroneous. Averaging relatively successful orientation performances with unsuccessful ones resulted in a distorted view of the outcome. The averaged scores are presented here for the reader's consideration. The analyses of insightful and non-insightful performances are presented in the following section.

The average error on each of the four trials is shown in Figure 4. The average error is 1444 meters on the first trial, dropping on subsequent trials to 1302, 1214, and 1171 meters. The two-way, repeated-measures analysis of variance showed this improvement to be statistically *significant*, $F\ (3, 81) = 30.07$, $p < .0001$.

The average error on the twelve different sites ranged from 314 meters (Site 4) to 2881 meters (Site 2). The analysis of variance

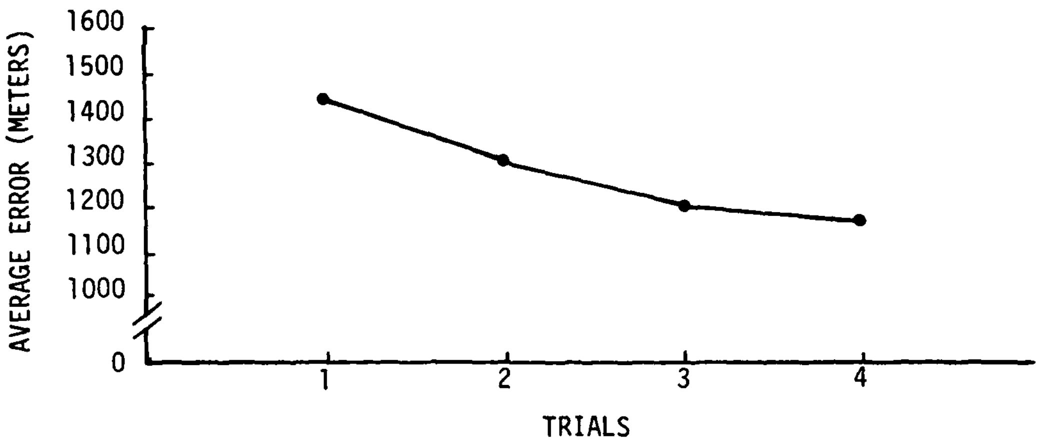


Figure 4. Average error over all 12 sites for Trials 1 through 4 of the experiment.

showed the error on sites to differ significantly, F (11, 297) = 14.38, $p < .0001$. The average error on the 12 sites is shown in Figure 5.

The analysis of variance did not indicate a significant Sites-by-Trials interaction. Such a lack of significance indicates that the improvement over trials was not consistently different at different sites.

It is instructive to examine the average performance of each of the 28 pilots who participated in the study. These data are plotted (for Trial 4) in Figure 6. No distinctive break is obvious in this distribution of scores. Instead, averages rise steadily from a low of 687 meters to a high of 1658 meters, suggesting a continuum of skill with some of the pilots performing consistently well and others performing consistently less well.

INSIGHTFUL PERFORMANCE

The nature of the *re-orientation* task (after a temporary disorientation) differs in at least one important respect from the task of *maintaining* one's orientation during the course of a flight. The aviator maintaining orientation knows from his pre-flight planning and his flight

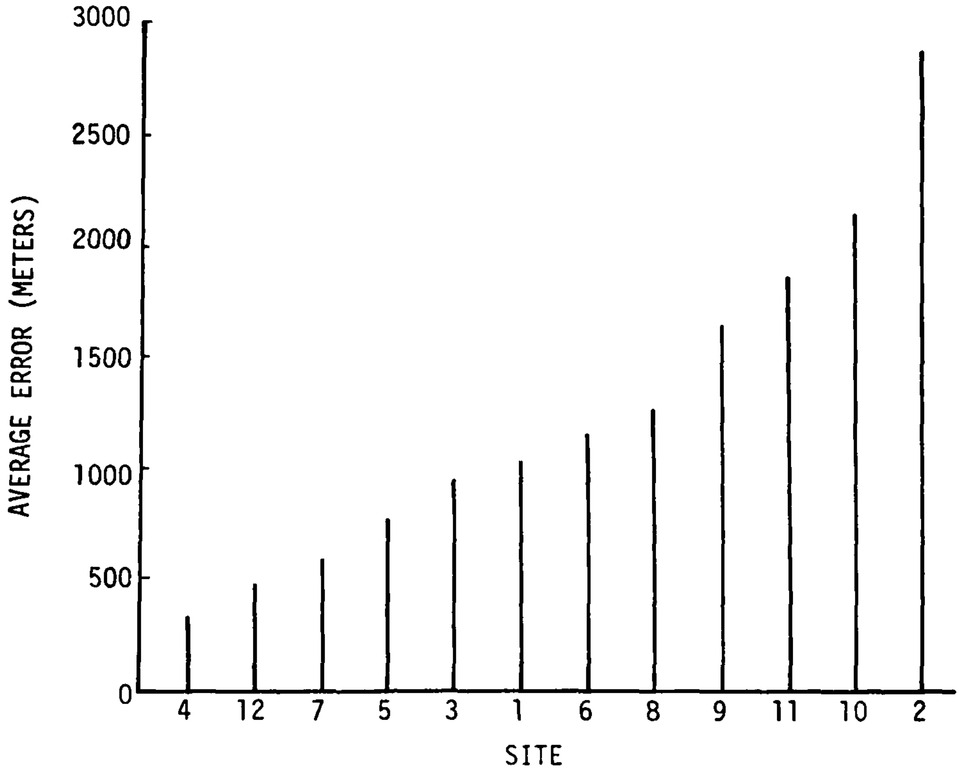


Figure 5. Average error over all 4 trials for the 12 sites, ranked by error magnitude.

course history just what checkpoint features are likely to become visible in upcoming moments. His task is that of "keeping track" of these expected features. Once disoriented, however, the aviator does not know what features he is likely to see since his position is unknown. His task is that of "problem solving"--trying to identify his position from map interpretation and terrain analysis.

Problem-solving tasks are characterized by the search for understanding rather than the search for gradual improvements typical in other learning tasks. Individuals are said to have *insight* when they solve a problem by perceiving the relationships essential to solution. In some cases insight is very sudden and one has what has been

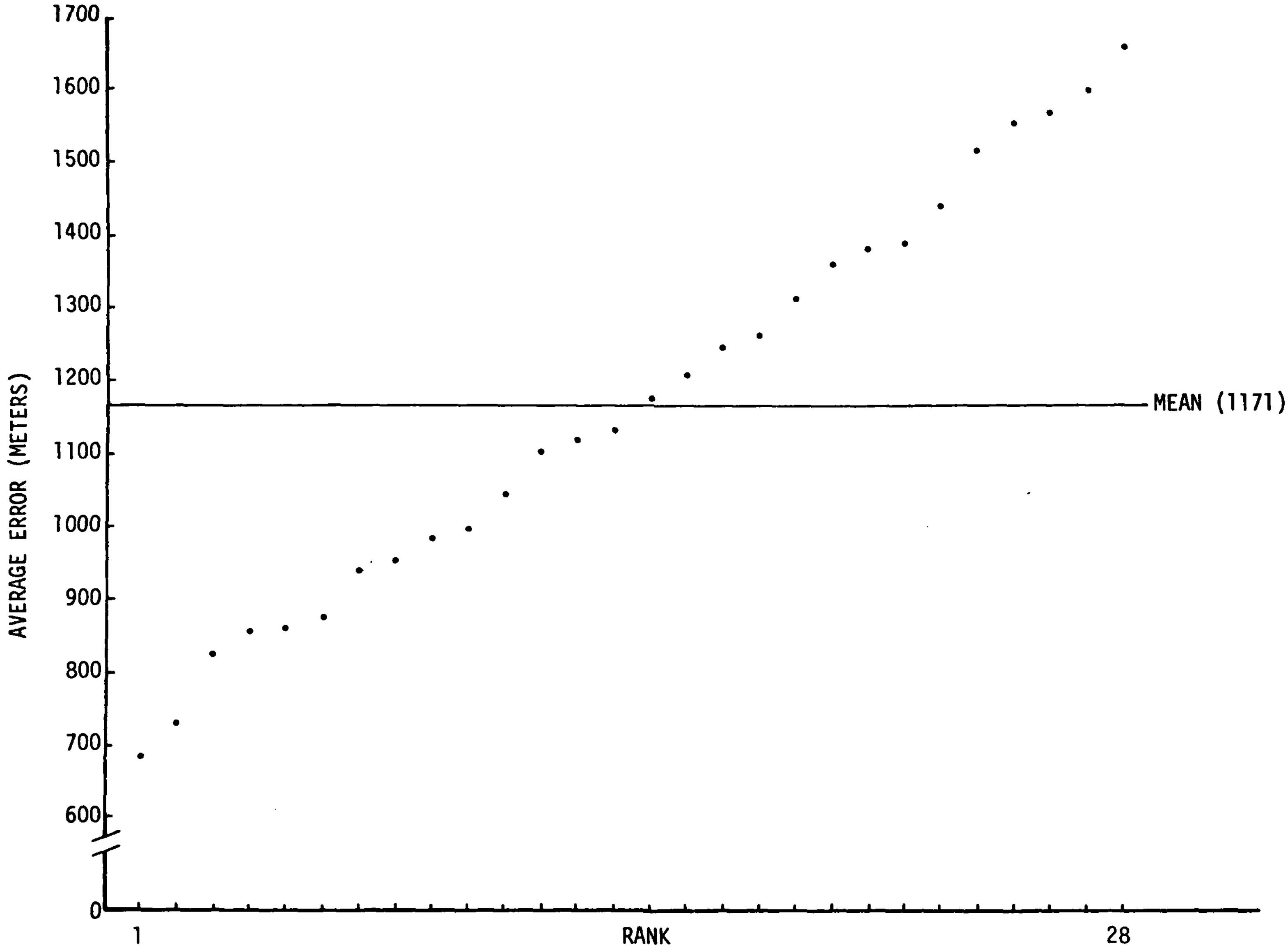


Figure 6. Average error over all 12 sites on Trial 4, for each of the 28 pilots, ranked by error magnitude.

appropriately called an "Aha" experience: the solution becomes clear as though a light had been turned on in the darkness.

Anecdotal evidence and the authors' personal experience suggest that re-orientation often comes as the result of an insight. Logical analyses can be applied to reduce the area of uncertainty, but it is not unusual for the terrain features and the map portrayal of the features to suddenly "fit" and re-orientation is achieved.

The error data for all participants, sites, and trials in the present experiment were reexamined to determine the relative frequency of sudden insightful solutions. An "insight trial" was operationally defined as the first trial on which the error for a given individual, on a given site, did not exceed 500 meters. A further proviso was that the error not exceed 500 meters on any subsequent trial at the same site. By this definition there were 336 opportunities for insight (12 sites x 28 pilots). Insight, as defined, occurred in 136 (40%) of these cases. These cases of insight were distributed over the four trials as shown in Table 1.

A stringent definition of "insight" must include a provision for suddenness of the change from disorientation to re-orientation. To examine the suddenness of insight as defined in this experiment, the 336 cases were divided into two groups: 136 insightful cases, and 200 non-insightful cases. For the non-insightful cases, the average error on each trial was plotted, just as it was in Figure 4. The average error was treated

TABLE 1

DISTRIBUTION OF INSIGHTS ACROSS THE FOUR TRIALS OF THE EXPERIMENT

	Trial 1	Trial 2	Trial 3	Trial 4	Total
Number of Insights	52	32	21	31	136
Percentage of Total Insights	38%	24%	15%	23%	100%
Percentage of Total Opportunities for Insight	15%	10%	6%	9%	40%

somewhat differently for the insightful cases. Since the insight trial could occur on any one of the four trials, it was necessary to find the average scores for each trial prior to and subsequent to the insight trial. For example, if an aviator achieved insight on the first trial, he would have no pre-insight trials but would have three post-insight trials. An aviator achieving insight on the third trial would have two pre-insight trials and one post-insight trial. Thus, the average error for the insightful cases was plotted for the insight trial and for the pre-insight and post-insight trials, regardless of the number of the trial. The results of this procedure are shown in Figure 7 . It is immediately evident from the figure that a very large drop in error is occurring between the trial immediately preceding insight and the insight trial itself. In fact, the average error drops 967 meters, from 1213 meters to 246 meters.

It is noteworthy that average error on the pre-insight trials was not decreasing. After the insight, error scores remain effectively unchanged (partly as a consequence of the definition of insight). The error scores of the non-insightful cases show no improvement across the four trials.

The meaning of the error difference between the three pre-insight trials and the first three non-insight trials is unclear. It is probable that some logical analyses have brought the insight group closer to the correct location than the non-insight group, but that the "aha" experience had not occurred. It is possible, however, that the closer position was achieved only by chance, but that this proximity increased the likelihood of the forthcoming insight. In any case, neither the insight cases nor the non-insight cases shows the gradual improvement suggested by Figure 4. The seemingly incremental increase in accuracy was merely an artifact of averaging the non-insightful cases with the increasing proportion of insight cases over the four trials.

The significant effect of performance differences on the 12 sites was re-examined in the light of the insight analysis. Figure 8 shows the

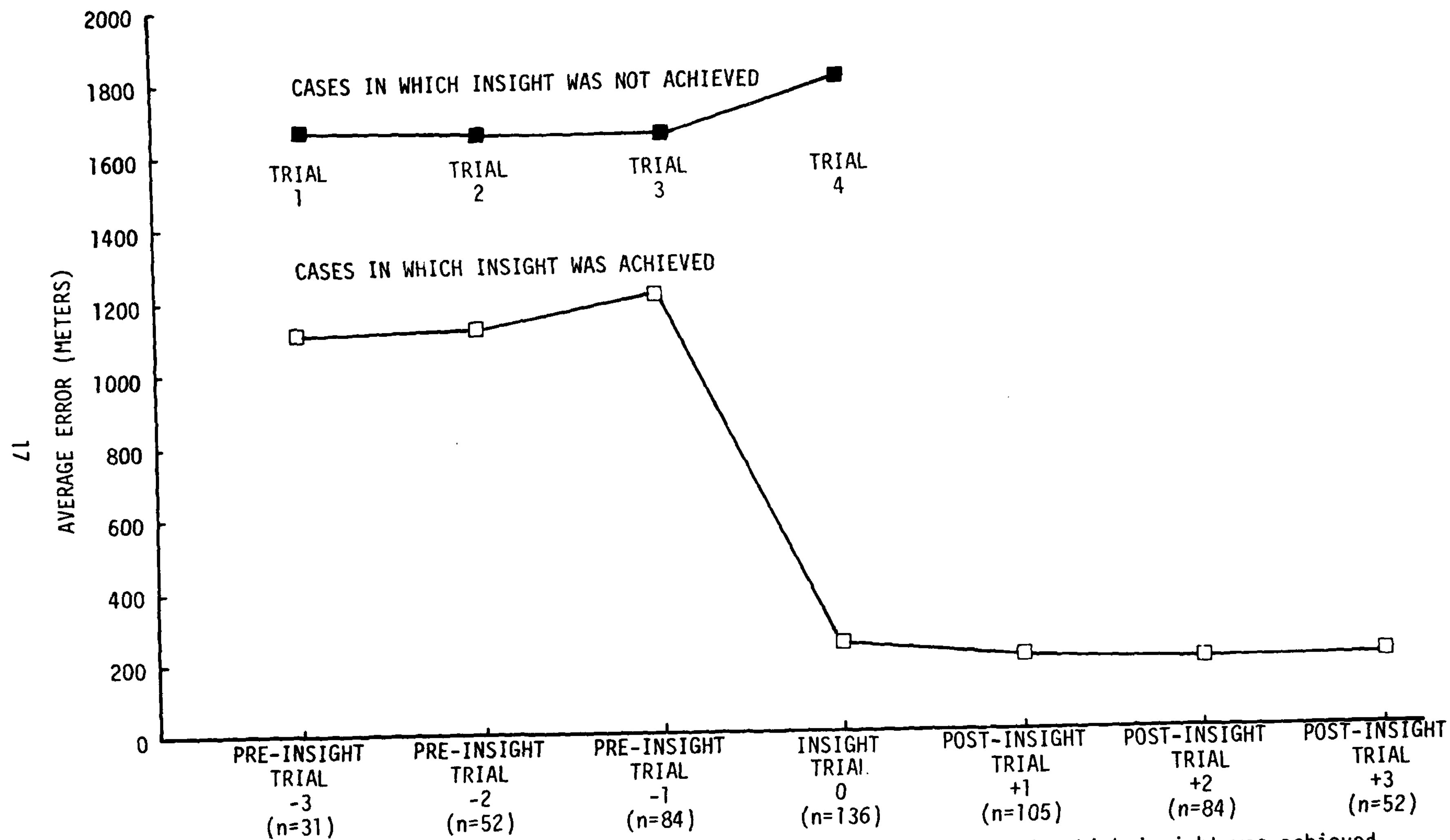


Figure 7. The average error before and after insight in those cases in which insight was achieved. Cases in which insight was not achieved are shown by Trial 1 through 4 for comparison.

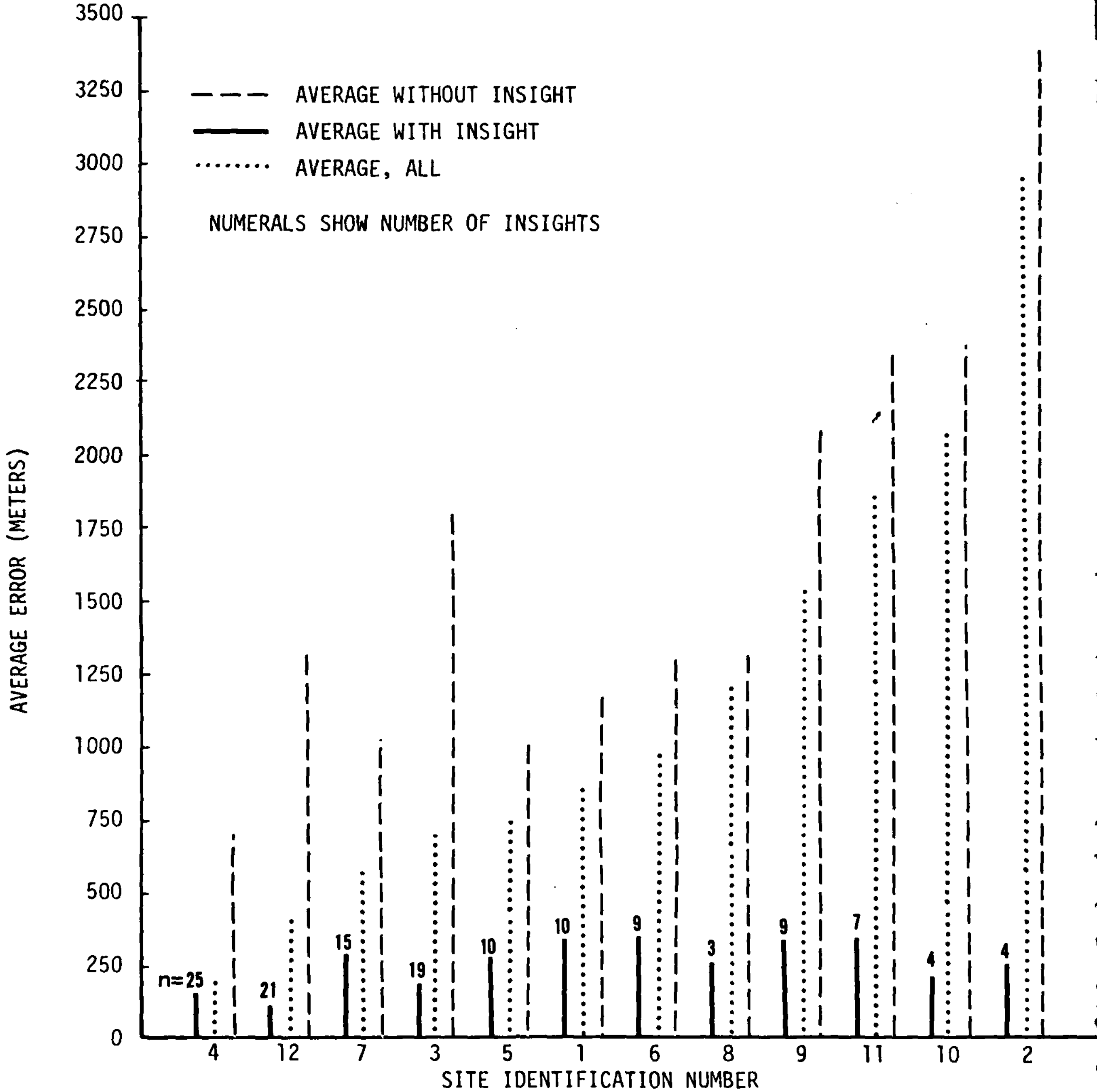


Figure 8. Average error on Trial 4 for the 12 sites, ranked by error magnitude, and averages for the insightful and non-insightful cases separately.

average error on Trial 4 on each of the 12 sites. Also shown in this figure are the averages for the insightful and non-insightful cases. By definition, the insightful cases show a small average error. The non-insightful cases average up to 3404 meters error. The numbers of insights for each of the sites are also shown in the figure. Thus it can be seen that all but three of the pilots discovered the approximate position of Site 4, but only four were able to determine the position of Site 2. On the average, 40% (11.33) of the 28 pilots were able to locate their position within 500 meters at any given site.

Is this successful 40% composed of the same group of pilots on every site? Do the best pilots tend to perform better than others even on sites for which they do not achieve insight? These questions were addressed by plotting the average error, for each pilot, of his insight and his non-insight cases. These averages are presented in Figure 9. This figure shows the pilots in rank order by their overall (combined insight and non-insight) averages on Trial 4. The histogram at the lower margin of the figures shows the insight averages for each pilot, and the + signs above show the non-insight averages. It is evident that, in general, the non-insight averages are as poor for the higher-ranked pilots as they are for the lower-ranked pilots. The highest ranked pilot, for example, had an average non-insight error level exceeded by only four other pilots.

The number of insights achieved by each pilot is shown in Figure 9 directly above the histogram. As would be expected, the number of insights are fairly well associated with the pilots overall rank. As a further check on performance trends, the number of insights for each pilot was correlated with his average error on Trial 4 on sites for which insight was not achieved. The correlation coefficient ($r = .26$) did not reach statistical significance, indicating that pilots most likely to achieve insight are not likely to have smaller error levels than others on the non-insightful cases.

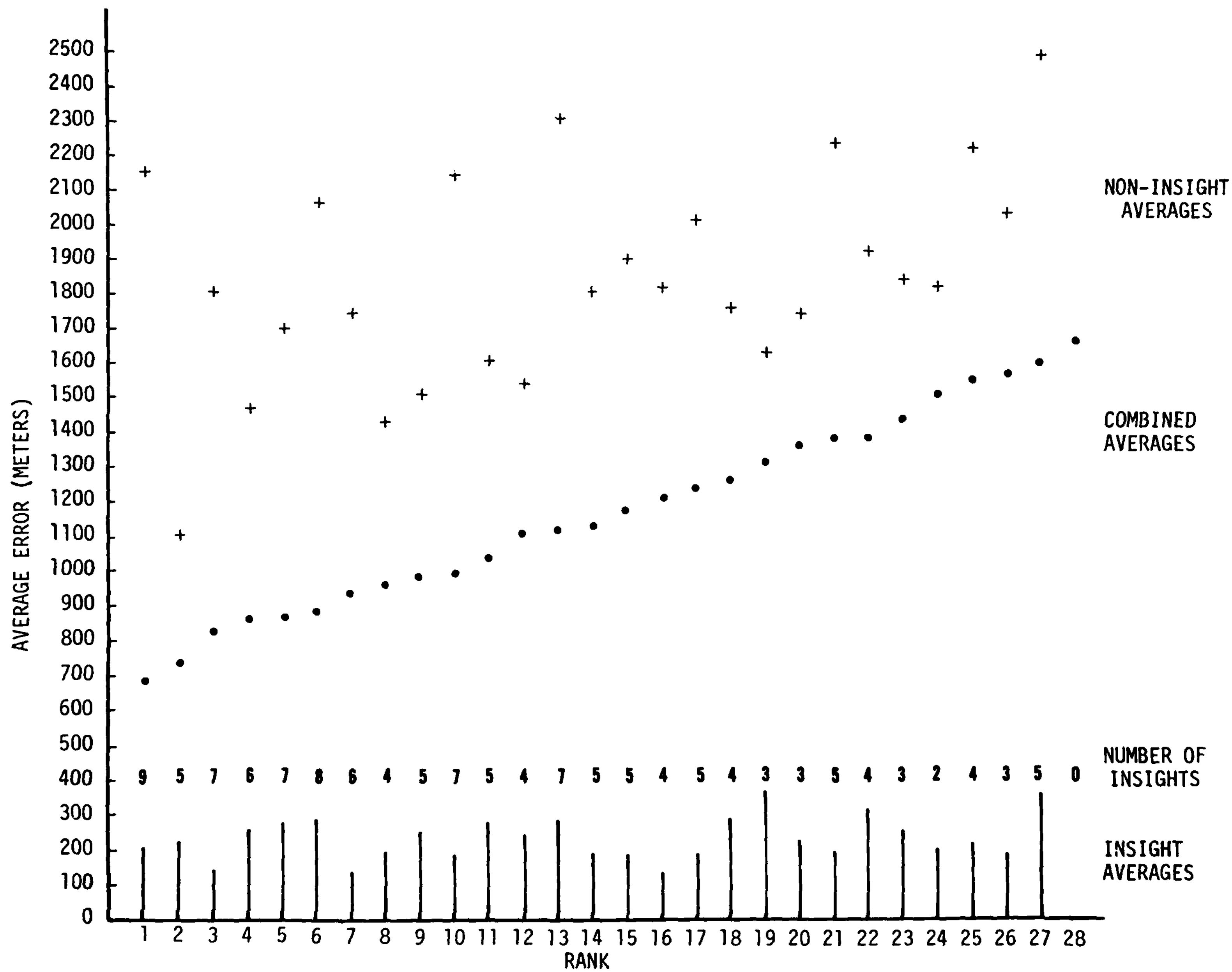


Figure 9. Pilots ranked by average performance on Trial 4 over all 12 sites, and averages for their insight and non-insight cases.

Figure 9 also shows that the highest-ranked pilots are not achieving a greatly disporportionate number of insights. The top-ranked 12 pilots are responsible for 54% of the insights; the lower-ranked 16 pilots achieved 46% of the insights. Even when the pilots are ranked by number of insights, the top 12 pilots are credited with only 57% of the insights. While some of the pilots are obviously performing better than others, it is also clear that insights are not restricted to an elite group.

EFFECT OF EXPERIENCE

The questionnaire data provided by the pilots prior to the conduct of the experiment included information on flight experience and self-appraisal. Specifically, pilots were asked to state the approximate number of hours of helicopter flight and hours of NOE flight each had experienced. In addition, the pilots were requested to rate themselves on their own ability to interpret terrain relief for orientation. The 1-9 scale used for the rating is shown in Appendix B. These three items of information were correlated with each pilot's overall average error on Trial 4, and with each pilot's total number of insights. The correlation coefficiencts are shown in Table 2. Whether the average error on Trial 4 or the total number of insights is used as an index of pilot performance, the correlations are quite similar. The number of total

TABLE 2

PEARSON PRODUCT MOMENT CORRELATIONS BETWEEN PILOTS' PERFORMANCE ON THE EXPERIMENTAL TASK, AND THEIR EXPERIENCE AND SELF-RATINGS

	HELICOPTER FLIGHT HOURS	NOE FLIGHT HOURS	ORIENTATION SKILL SELF-RATING
Trial 4 Average Error	.11	-.40	.01
Total Number of Insights	.08	.35	.13

helicopter flight hours shows no significant correlation with performance on this low-altitude re-orientation task. On the other hand, hours of NOE flight experience are well-correlated with re-orientation performance. The negative ($r = -.40$) correlation shows that as number of NOE hours increases, magnitude of error decreases. The positive ($r = .35$) correlation indicates that number of insights increases with increasing NOE flight hours. The self-ratings of ability to interpret terrain relief were not significantly correlated with performance of the experimental task.

CHAPTER IV
CONCLUSIONS

This chapter provides an interpretation of the findings of the experiment with an emphasis on performance differences at the various sites, and specific types of difficulties encountered by the aviators. A summary of findings is also presented.

INTERPRETATION OF FINDINGS

Performance on the re-orientation task tended to be dichotomous--either the aviators had located the (approximately) correct site or they had not. On the first trial, only a few discovered the correct site, but an increasing number achieved the map-terrain "fit" with additional trials. Those who had not experienced insight showed no improvement with additional trials on each site. The inference that error was gradually reduced with repeated trials was shown to be false; the apparent gradual reduction of error was only an artifact of averaging the changing proportions of insight cases with non-insight cases over the four trials.

While some aviators achieved more insights than others, their performances on sites at which they did not achieve an insight were no better than those of other non-insightful aviators. Furthermore, it was evident that although some of the aviators achieved many more insights than others, insights were not achieved only by the most skilled aviators. Examination of the data revealed that the "best" aviators sometimes did not achieve insights at sites correctly identified by the aviators with a below-average number of total insights. Thus, the inference that the aviators most skilled at this kind of task would perform consistently better than others on all sites was shown to be incorrect.

It was clear that the various terrain types at the sites provided a broad range of difficulty. Although the specific variables related to site difficulty cannot be completely defined or controlled, certain observations can be made regarding the ease or difficulty of achieving insight at various sites. The most important factors in discovering the correct site location on the map appear to be the presence of multiple cultural features such as roads and buildings, and the correspondence of these features in the terrain with their portrayal on the map. The greatest numbers of insights were achieved on Sites 4, 12, and 3. All of these sites were located on roads that were portrayed on the map, and other cultural features present in the terrain and depicted on the map were useful in deducing the correct position.

A road, by itself, was not sufficient for position identification. Sites 6 and 10, for example, were located near roads that were clearly visible in the photograph and depicted on the map, but additional cultural featues were not visible (Site 10) or helpful (Site 6). Thus, the incorrectly identified positions were distributed thousands of meters along the roads at these two sites.

A heavy dependence upon cultural features caused some of the aviators to be misled when these features were not depicted on the maps. The terrain visible at Sites 1 and 11 included roads that had been constructed after the map had been compiled. This lack of correspondence contributed to the failure to achieve insight at these positions even though other cultural features were present at both sites and depicted on the maps.

Sites associated with the smallest numbers of insights and greatest average errors were those with the least cultural features. These sites were unlikely to be correctly identified unless the aviator could interpret contour information on the map. Site 8, for example, was devoid of cultural features and only three insights were achieved at this location. Only four insights were achieved at Sites 10 and 2, as cultural information was scant, although landform contours were quite evident. The correct location of Sites 6, 9, and 11 also demand some skill in contour interpretation, and these sites were associated with fewer than average insights.

It is noteworthy that in the previous study,[3] only contour information was available for geographic orientation and performances were not correlated with total helicopter flight hours *or* NOE flight hours. In the present study, all types of terrain features were included on the maps. Again, performances were not correlated with total flight hours. Performances *were*, however, correlated with NOE flight hours. This difference suggests that increasing hours of NOE flight are associated with better geographic orientation performances only as long as all types of terrain features are available for use as checkpoints.

In addition to the modest contour interpretation skills evidenced by some of the aviators, two other types of problems were observed in task performances. The first of these problems is that of "locking on" an incorrect site and not using additional terrain views to improve upon the first estimate of the site's position on the map. Seven of the pilots tended to achieve insight either on the first trial, or not at all. More than 10% of the non-insightful cases could also be attributed to this failure to improve upon the first estimate of position. It was as if aviators sometimes "talked themselves into" the correctness of a position even though evidence was available to disprove their initial hypotheses.

Another type of problem detected in task performance was the failure to productively employ azimuth information. It was not possible to examine the aviator's use of resection from specific terrain features, but certain types of blunders indicated that compass information either was ignored or misinterpreted. At Site 1, for example, a road and railroad were clearly visible to the west of the site. Nevertheless, nine of the aviators indicated that the site position was to the west of these features, even after

[3] Rogers, S. P. & Cross, K. D. *Accuracy of geographic orientation during nap-of-the-earth flight as a function of topographic map contour-line interval.* Santa Barbara, California: Anacapa Sciences, Inc., December, 1978.

the fourth trial. Similar types of errors were detectable at other sites, although fewer aviators committed them than at the first site.

SUMMARY OF FINDINGS

1. Recovery from geographic disorientation is a problem-solving task and is characterized by sudden insight rather than gradual improvements in position-finding.

2. When "insight" was defined as error less than 500 meters, insightful position estimates averaged about 250 meters from the correct site; non-insightful estimates averaged about 1700 meters from the correct site.

3. The average NOE aviator achieved insight on about 5 of the 12 sites (after 4 views of the sites). Aviator performance ranged from 0 to 9 insights.

4. On the average, about 40% of the aviators achieved insight at any given site (after four views of the sites), but site difficulty ranged from insight by only 11% of the aviators to insight by 89% of the aviators.

5. Some insights were achieved by nearly all aviators; insights were not restricted to an elite minority.

6. Number of insights achieved by aviators were correlated with their hours of NOE flight experience.

7. Sites associated with greatest numbers of insights and lowest error levels were those with multiple cultural features; sites that demanded contour interpretation for orientation were associated with the lowest numbers of insights and highest error levels.

APPENDIX A

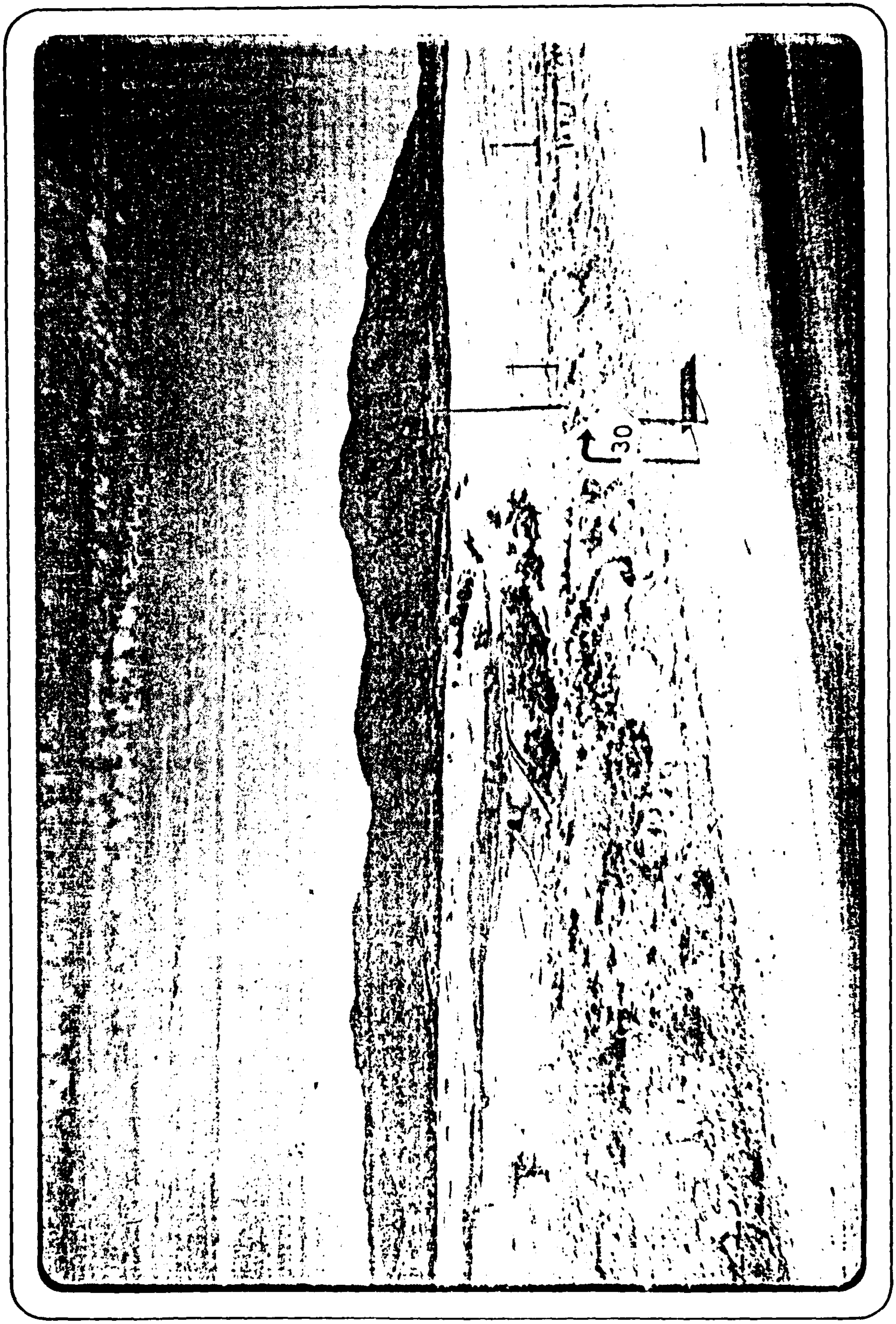
GRAPHIC SUMMARY OF EXPERIMENTAL DATA

Statistical analyses of average error levels do not clearly identify the nature of the difficulties encountered by the aviators in their attempts to become re-oriented after temporary disorientation. This appendix provides a graphic summary of the experimental data for the reader's review and analysis.

The subsequent pages of this appendix offer the following information for each of the 12 sites:

- A photograph taken from the site, showing 65° of the SURNOT's 360° field of view.
- A map segment from the map sheet used by the aviators, showing the correct location of the site and the area of uncertainty.
- Data pertaining to the correspondence of the map sheet and the depicted terrain.
- Data regarding the aviators' accuracy in performance of the re-orientation task.

An arrow on each map segment shows the exact location from which the photograph was taken. The site, as identified by the 28 aviators on Trial 4, is depicted by round dots. This portrayal of the experimental data provides an unambiguous overview of error distributions. The average error, standard deviation, range, and percent of responses within various distances from the correct site, are shown to the lower left of the map segment. The "readily identifiable features" and "confusion factors" detailed to the left of the map segment are useful in interpreting the types of errors made by the aviators and subjectively judging the apparent difficulty of re-orientation at these sites.



Site 1. Tehachapi, California. View to the west.

SITE 1

TEHACHAPI

Contour Interval - 100 feet

READILY IDENTIFIABLE FEATURES

Cemetery at 130°

Black Mountain 295°

Bend in the railroad track 280°

Chapi Hill 45°

Presence of road bending around site from west to south

CONFUSION FACTORS

Unportrayed buildings to northwest

Unportrayed new road north of site

ACCURACY OF ORIENTATION (Trial 4)

Average error: 858m (S.D. 622m)

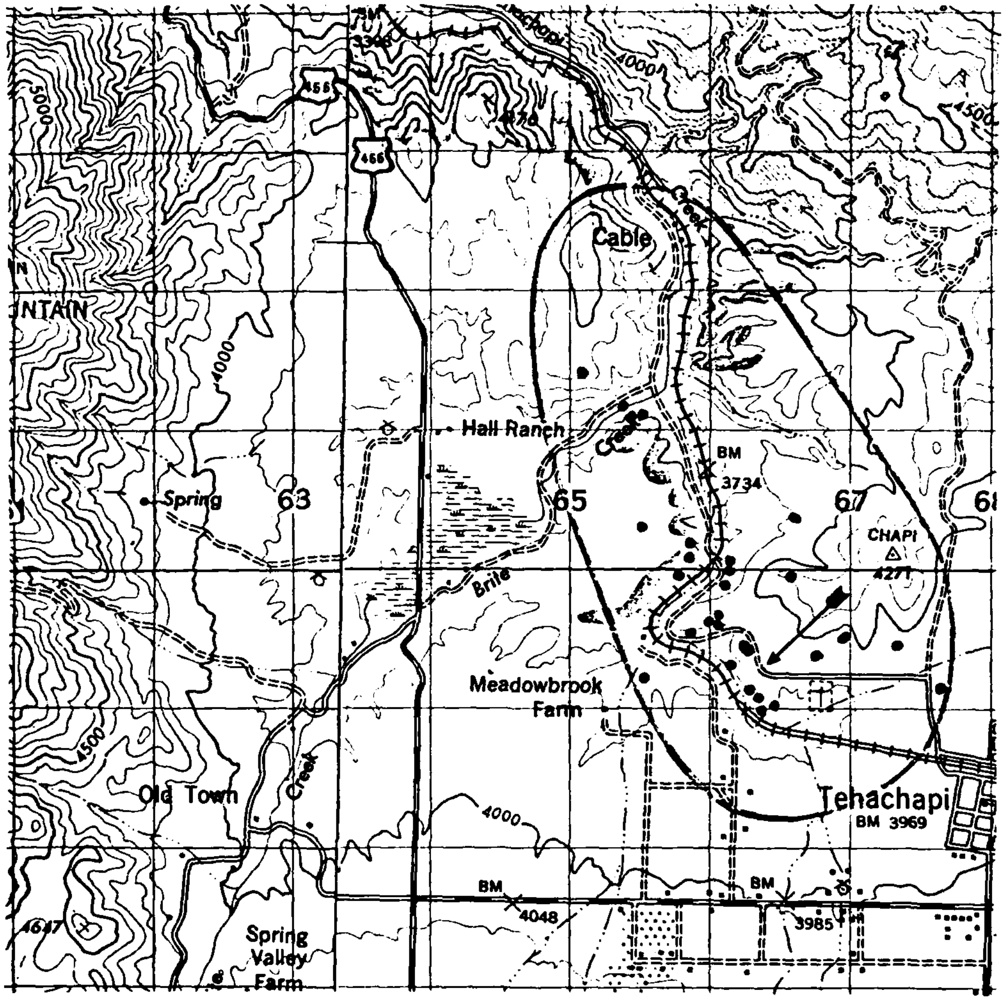
Range: 200 to 2500 meters

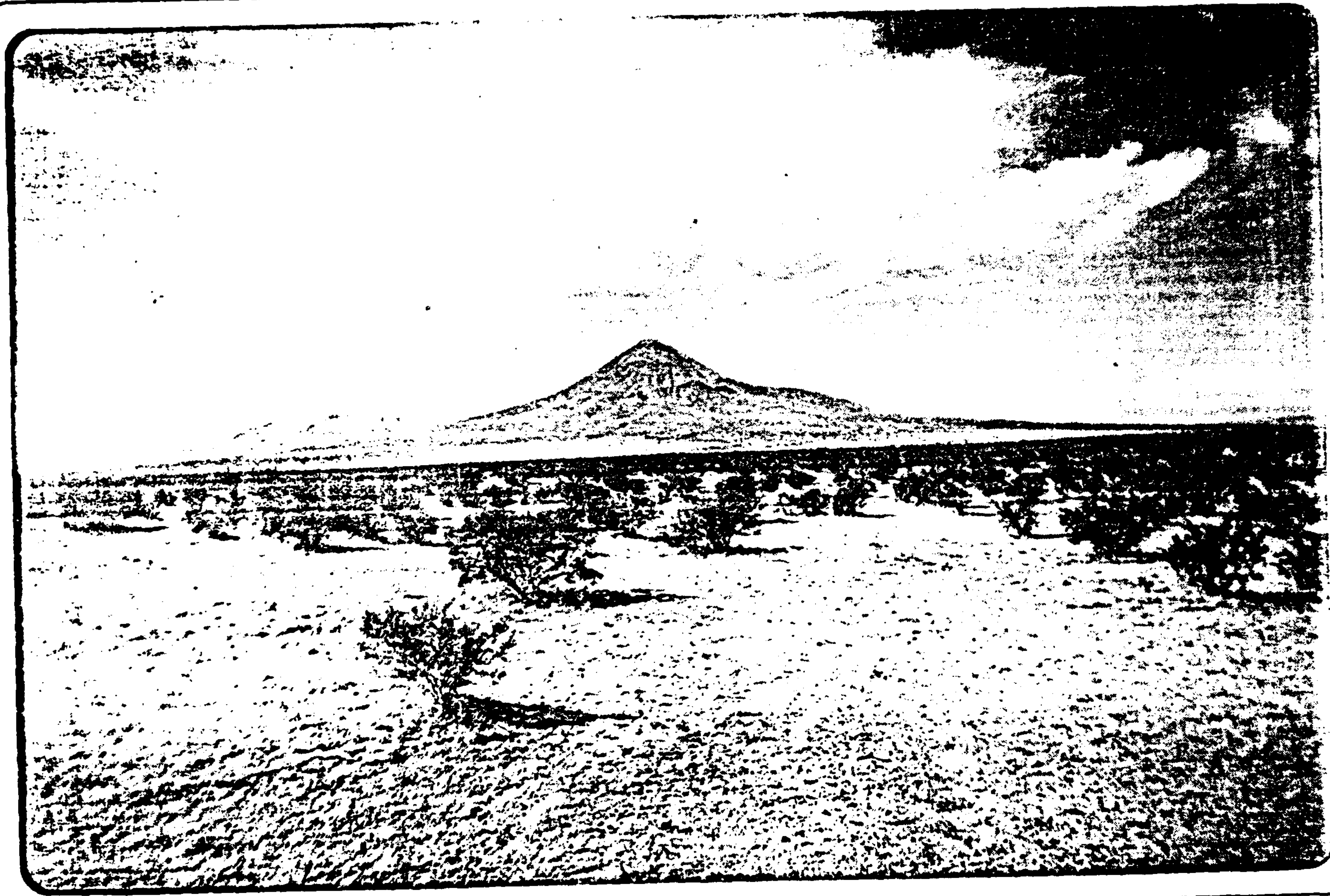
Percent within 100 meters: 0%

500 meters: 36%

1000 meters: 75%

Percent beyond 2000 meters: 14%





Site 2. Mojave, California. View to the southeast.

SITE 2

MOJAVE

Contour Interval - 100 feet

READILY IDENTIFIABLE FEATURES

- Railroad track to south
- Dirt road to southeast
- Water tank at 55°
- Distinctive hills at 235°, 190°, and 140°
- The site is located on top of a small hill.

CONFUSION FACTORS

The presence of hills in a similar spatial arrangement surrounding Hill 2818 to the southeast.

ACCURACY OF ORIENTATION (Trial 4)

Average error: 2953m (S.D. 1479m)

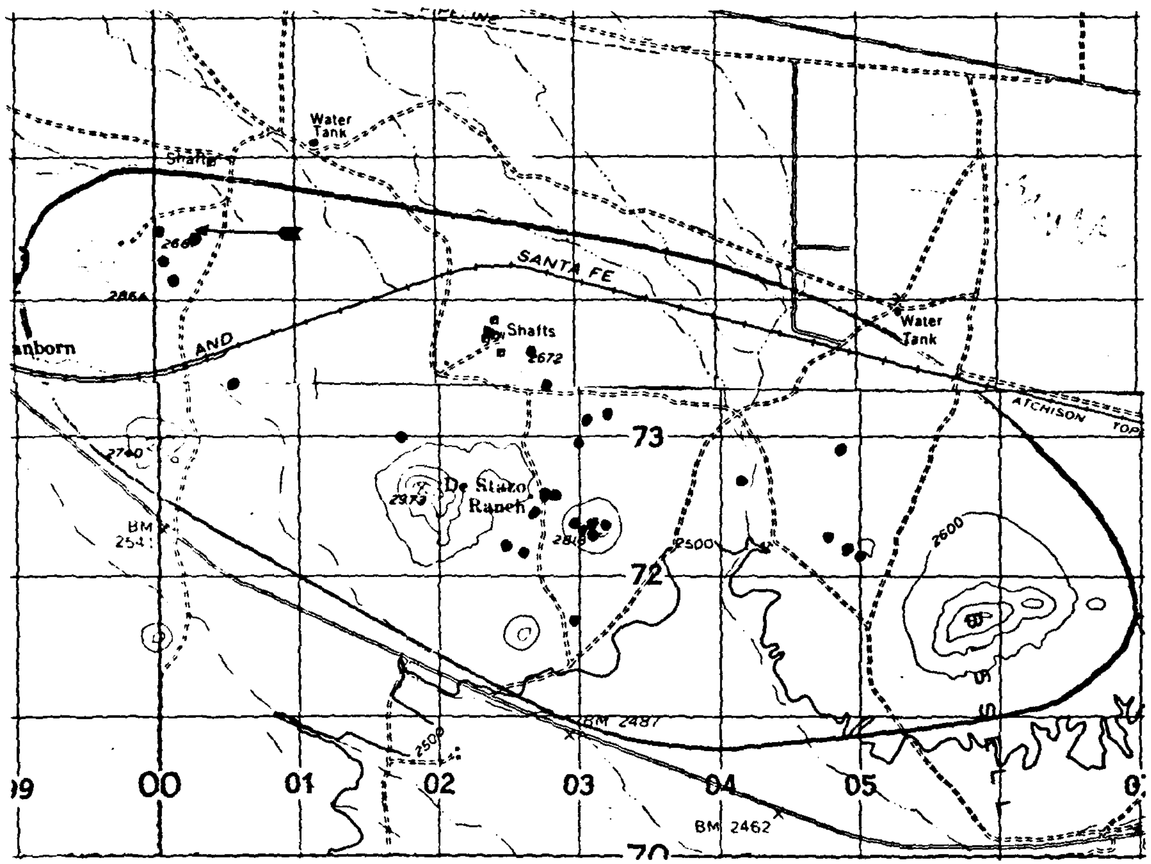
Range: 0 to 5450 meters

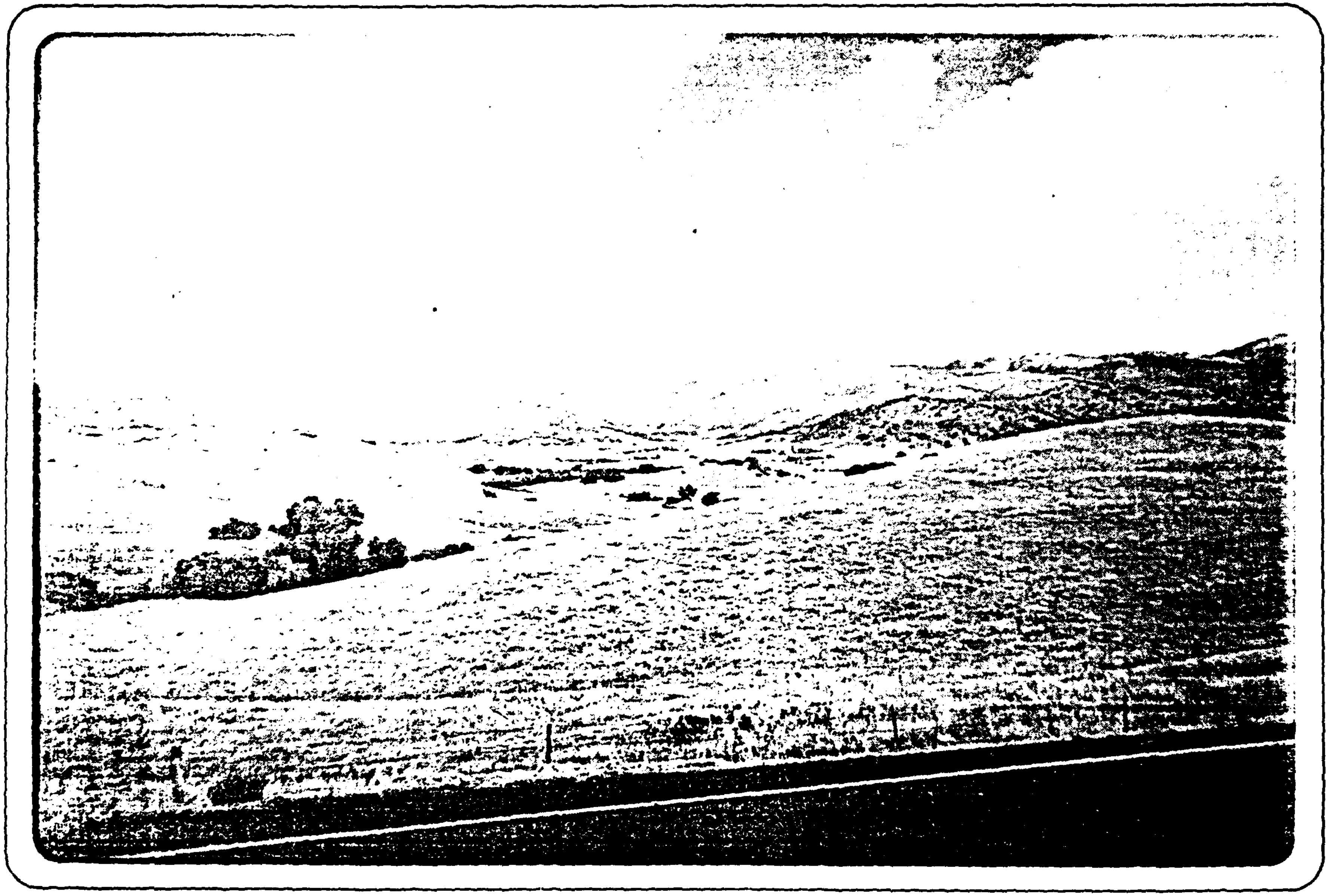
Percent within 100 meters: 4%

500 meters: 14%

1000 meters: 14%

Percent beyond 2000 meters: 79%





Site 3. Santa Ysabel, California. View to the north.

SITE 3

SANTA YSABEL

Contour Interval - 80 feet

READILY IDENTIFIABLE FEATURES

Presence of adjacent road to the north of the site running from southwest to northeast.

Prominent bluff at 90°

Bend in road at 80°

Buildings and road intersection at 70°

Hilltop at 305°

Upward slope to the south

CONFUSION FACTORS

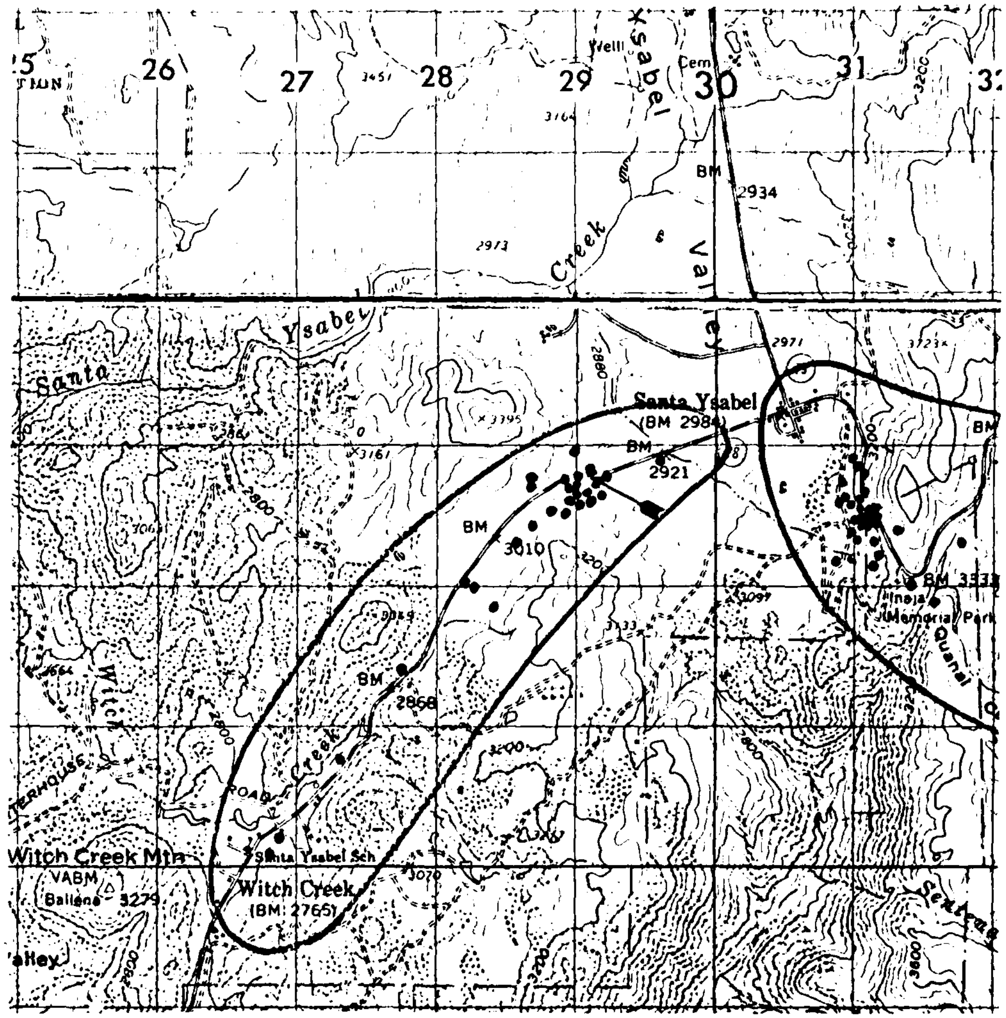
None

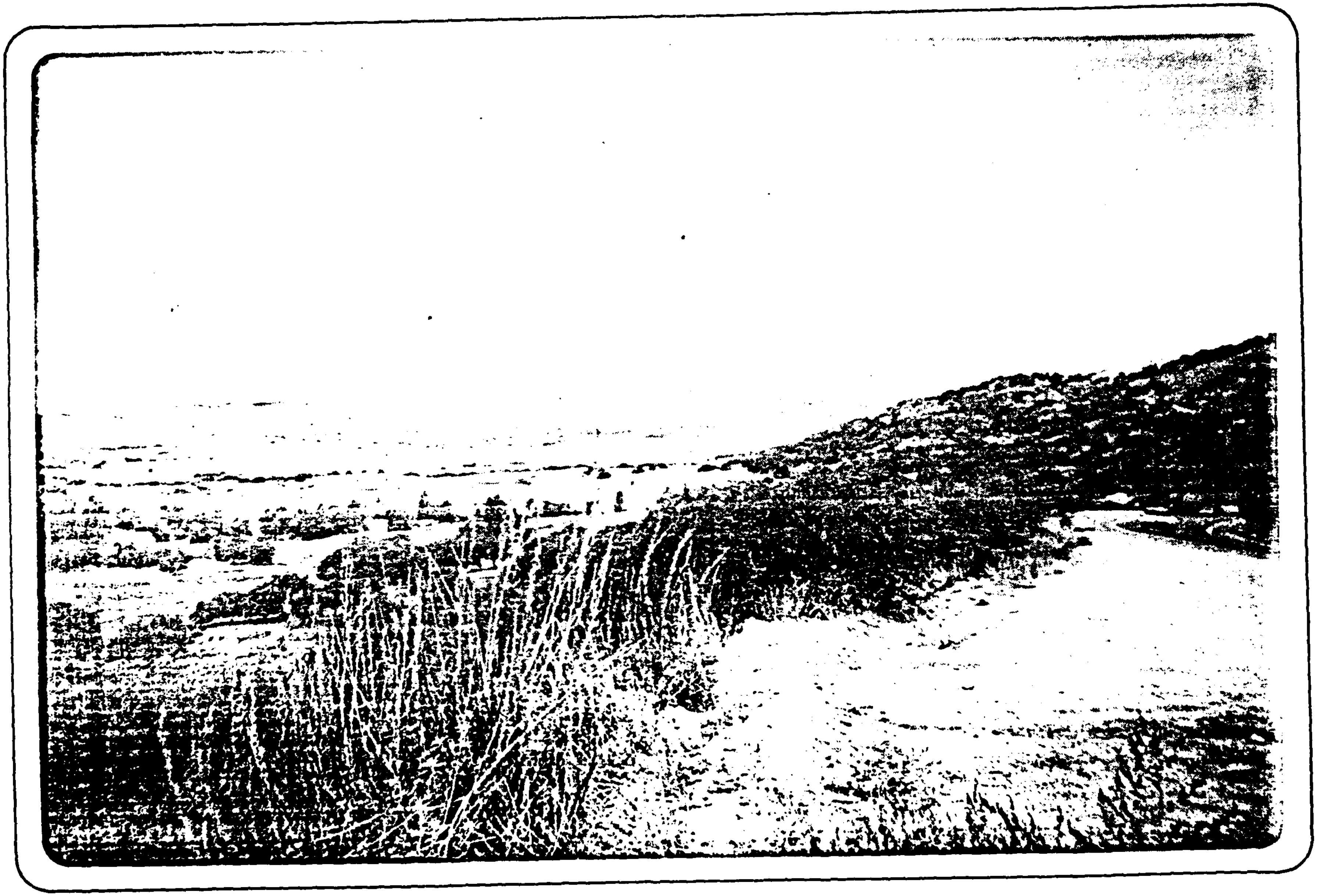
ACCURACY OF ORIENTATION (Trial 4)

Average error: 705m (S.D. 956m)

Range: 0 to 3500 meters

Percent within 100 meters:	29%
500 meters:	68%
1000 meters:	75%
Percent beyond 2000 meters:	11%





Site 4. Santa Ysabel, California. View to the northwest.

SITE 4

SANTA YSABEL

Contour Interval - 80 feet

READILY IDENTIFIABLE FEATURES

Town at 320°

Mountain peak behind town at 320°

Road to east of site running approximately north and south.

Steep bluff to east of road

Dirt roads and small hills to the southwest

CONFUSION FACTORS

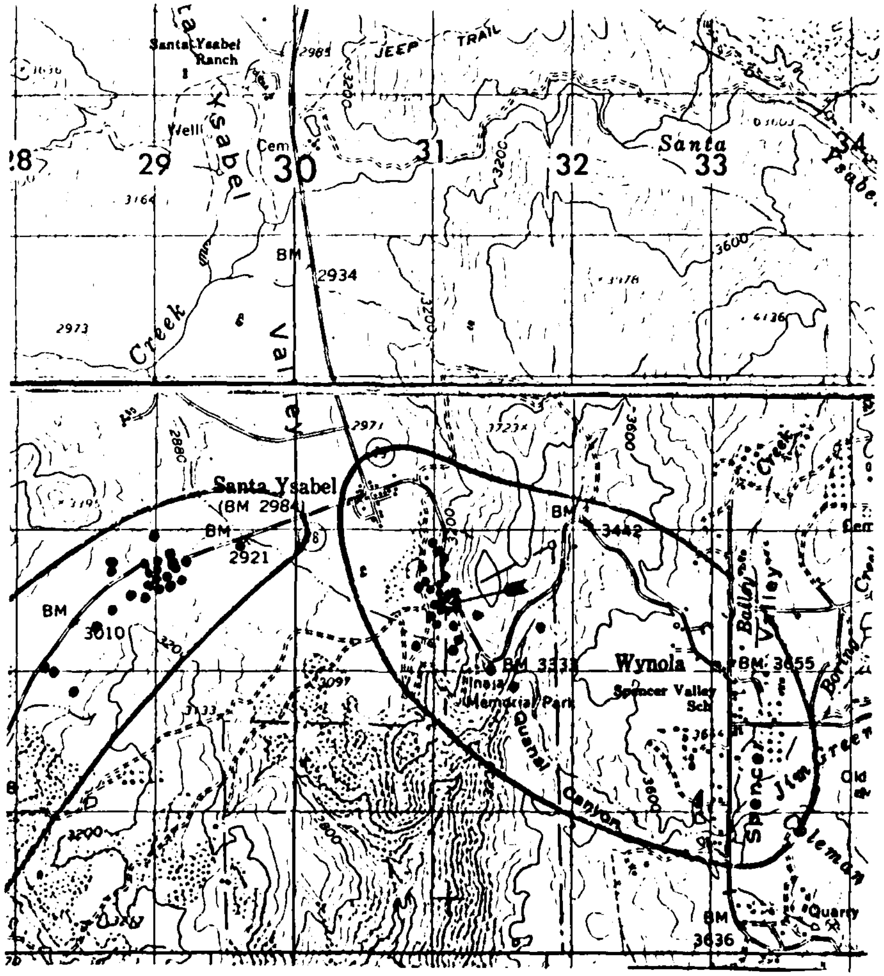
None

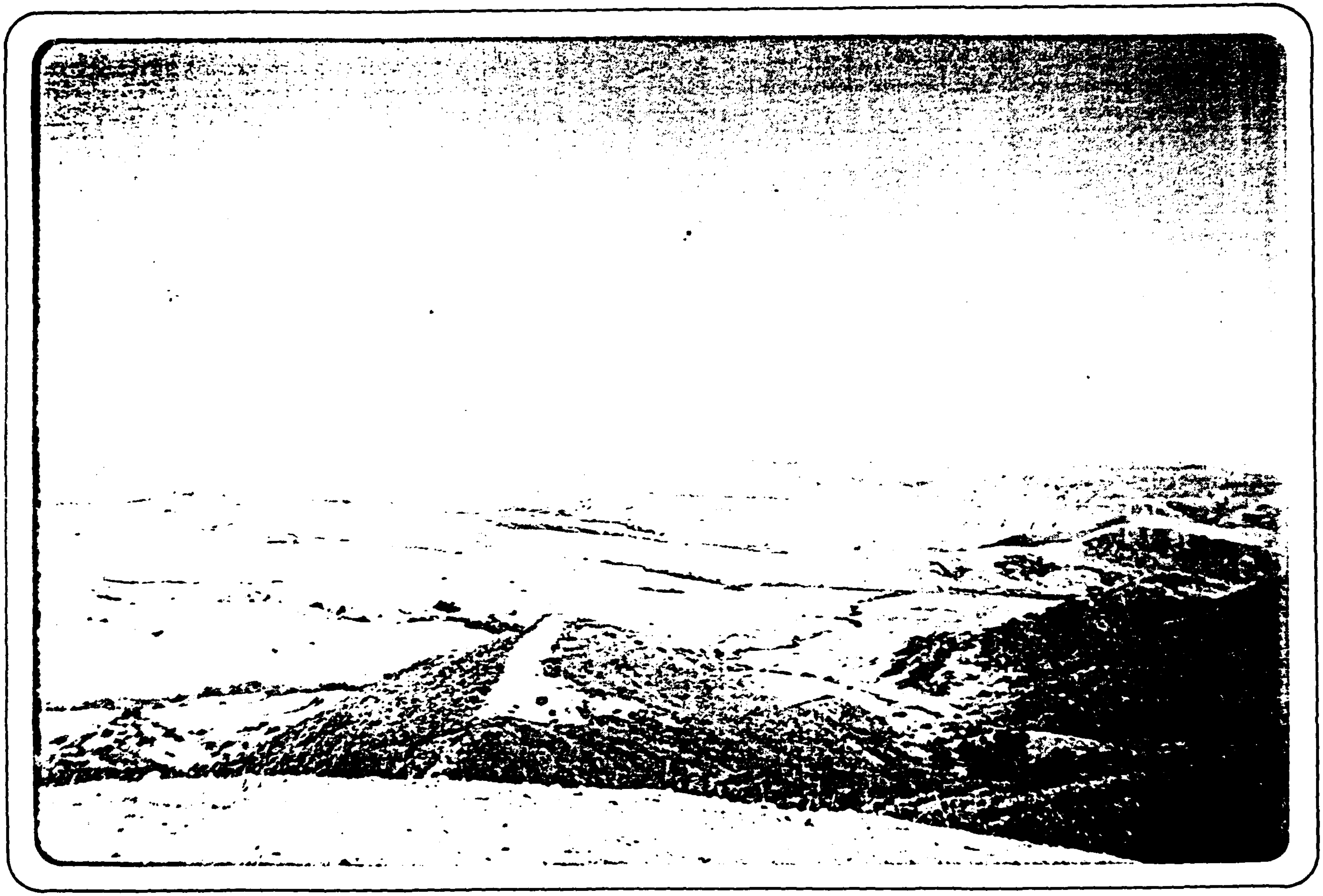
ACCURACY OF ORIENTATION (Trial 4)

Average error: 200m (S.D. 206m)

Range: 0 to 800 meters

Percent within	100 meters:	43%
	500 meters:	89%
	1000 meters:	100%
Percent beyond	2000 meters:	0%





Site 5. Camp Pendleton, California. View to the east.

SITE 5

CAMP PENDLETON

Contour Interval - 40 feet

READILY IDENTIFIABLE FEATURES

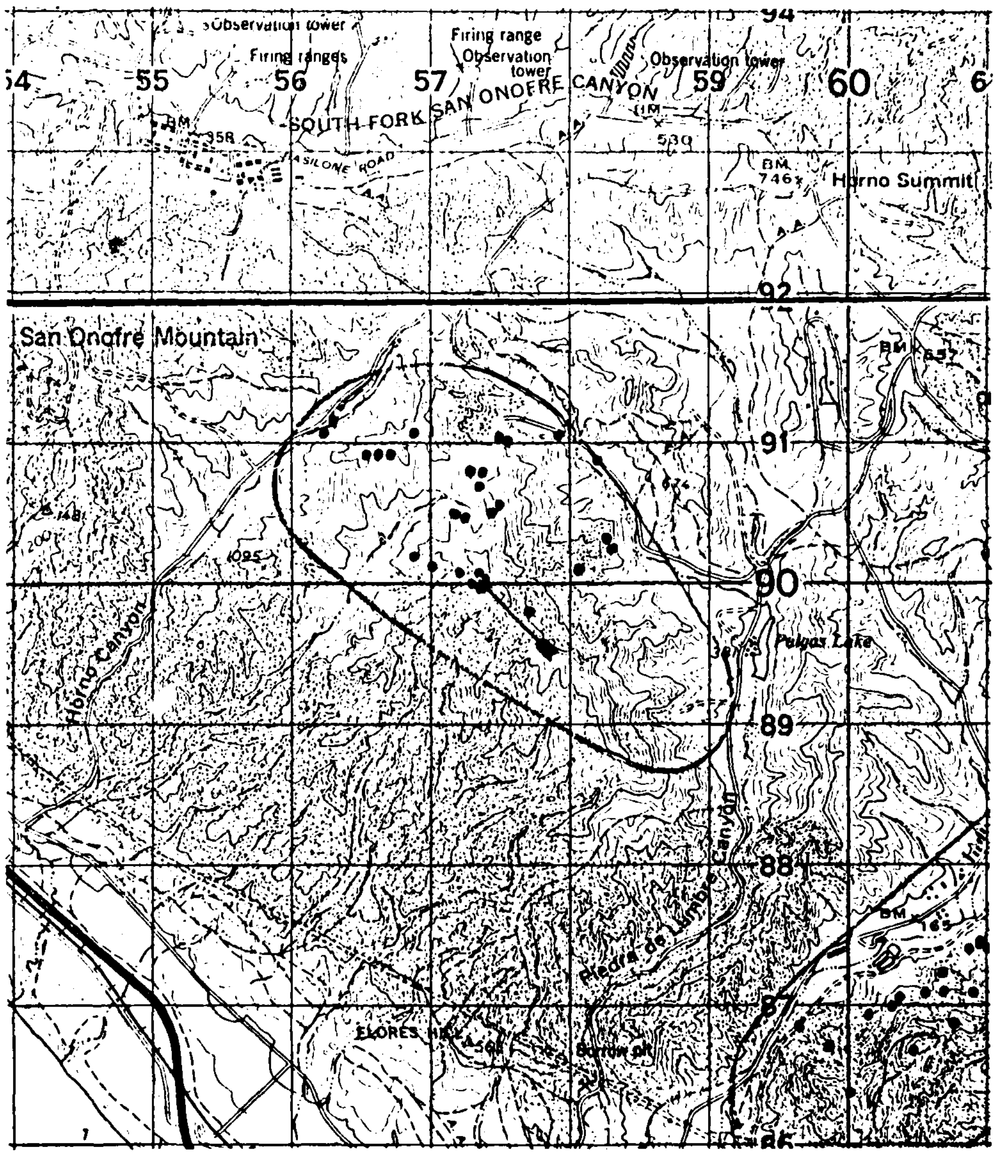
San Onofre Mountain to the northwest
Southern end of Horno Canyon at 240°
Ridge lines to the southwest
Site location on high ground
Valley to the northeast

CONFUSION FACTORS

The presence of other prominent hilltops

ACCURACY OF ORIENTATION (Trial 4)

Average error: 737m (S.D. 442m)
Range: 0 to 1500 meters
Percent within 100 meters: 14%
500 meters: 36%
1000 meters: 71%
Percent beyond 2000 meters: 0%



Site 6. Camp Pendleton, California. View to the northeast.

SITE 6

CAMP PENDLETON

Contour Interval - 40 feet

READILY IDENTIFIABLE FEATURES

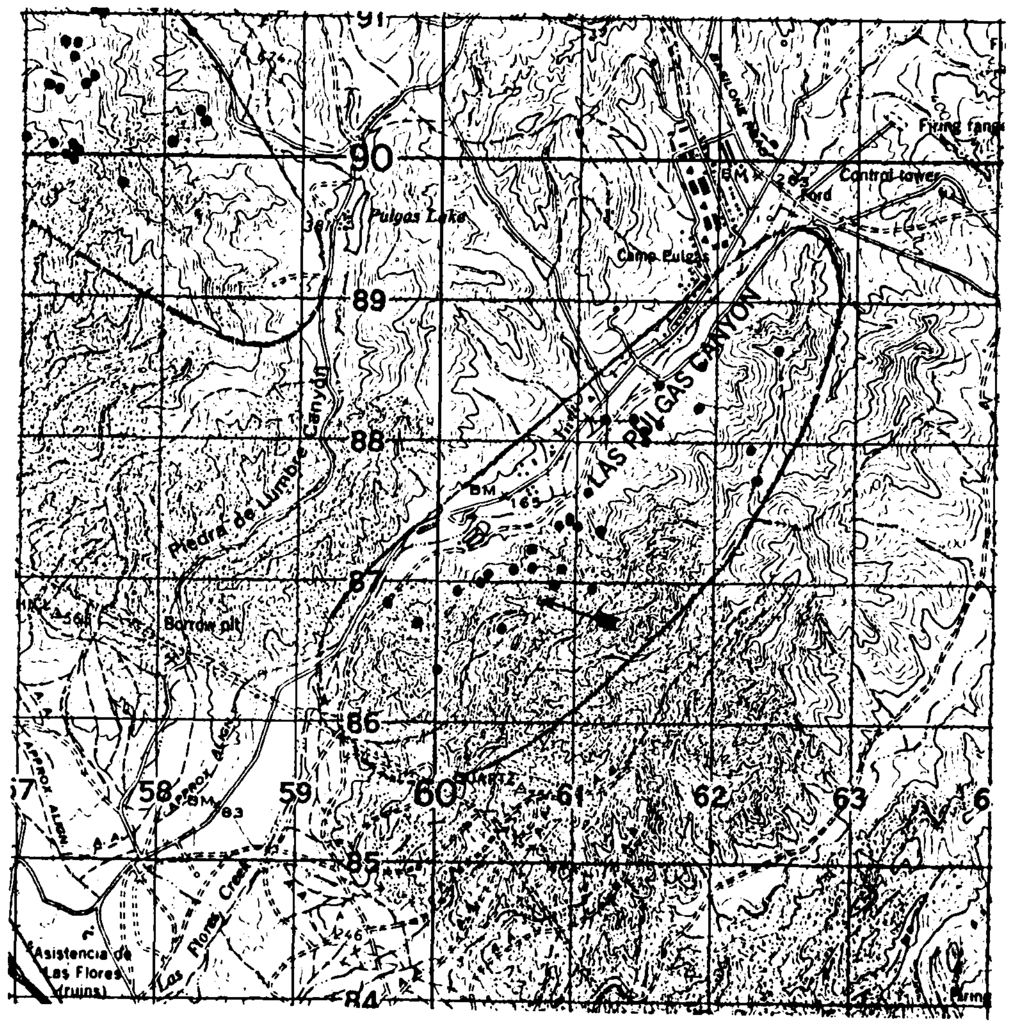
Road visible to north running northeast
Large group of buildings at 25°
Secondary road paralleling primary road
Location of site on a prominent hilltop
Line of hills to west of site
Ocean to southwest of site

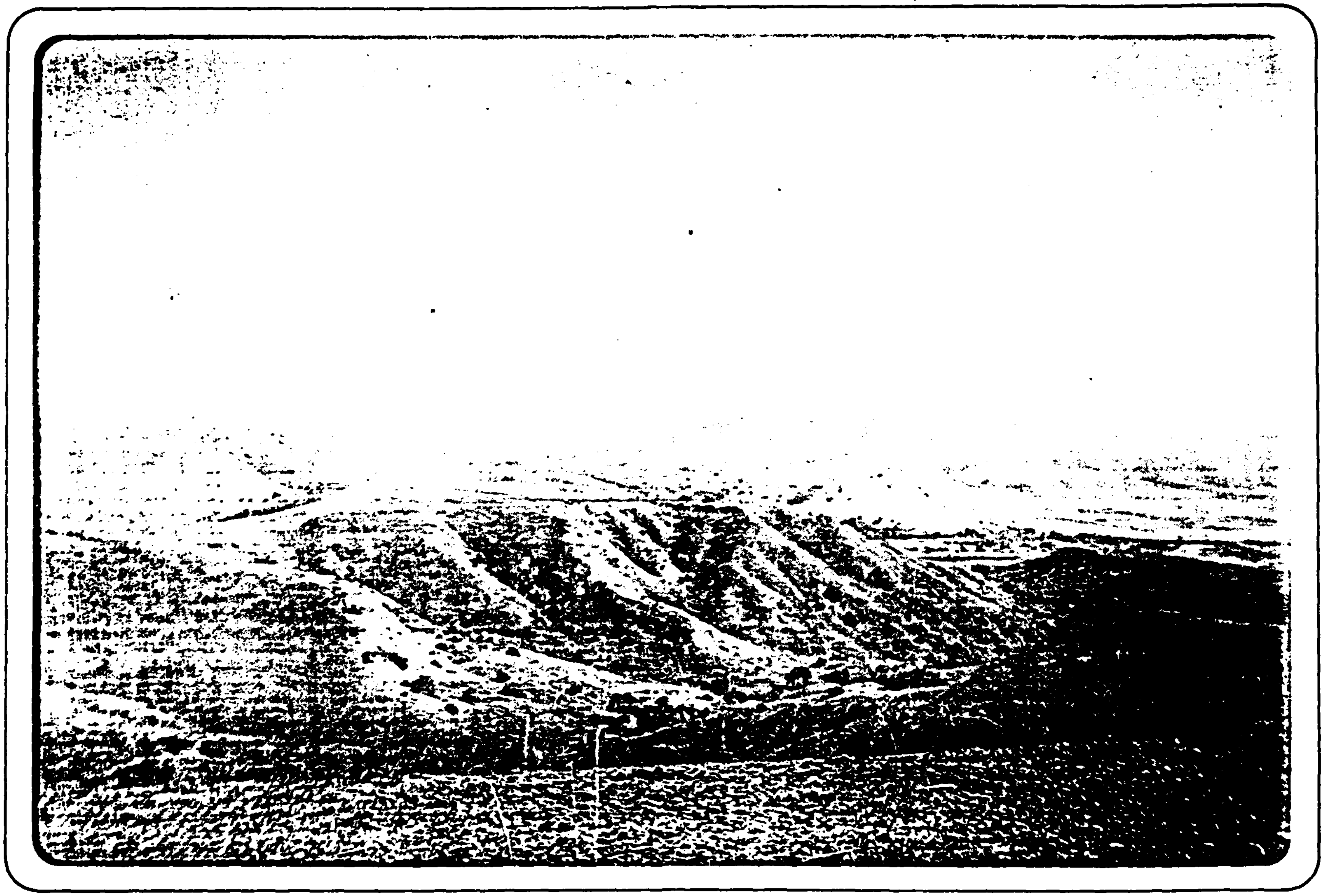
CONFUSION FACTORS

Prominent pond is hidden by foliage

ACCURACY OF ORIENTATION (Trial 4)

Average error: 977m (S.D. 628m)
Range: 200 to 2400 meters
Percent within 100 meters: 0%
500 meters: 32%
1000 meters: 54%
Percent beyond 2000 meters: 7%





Site 7. Camp Pendleton, California. View to the southeast.

SITE 7
CAMP PENDLETON

Contour Interval - 40 feet

READILY IDENTIFIABLE FEATURES

Firing range targets visible to southeast

Distinctive hill at 135° and 260°

San Mateo Canyon to the east running in a northeasterly direction

Valley running into San Mateo Canyon at 130°

Distinctive landforms to the southeast

Roads visible to the south

CONFUSION FACTORS

Other similar landforms surrounding the site

ACCURACY OF ORIENTATION (Trial 4)

Average error: 570m (S.D. 413m)

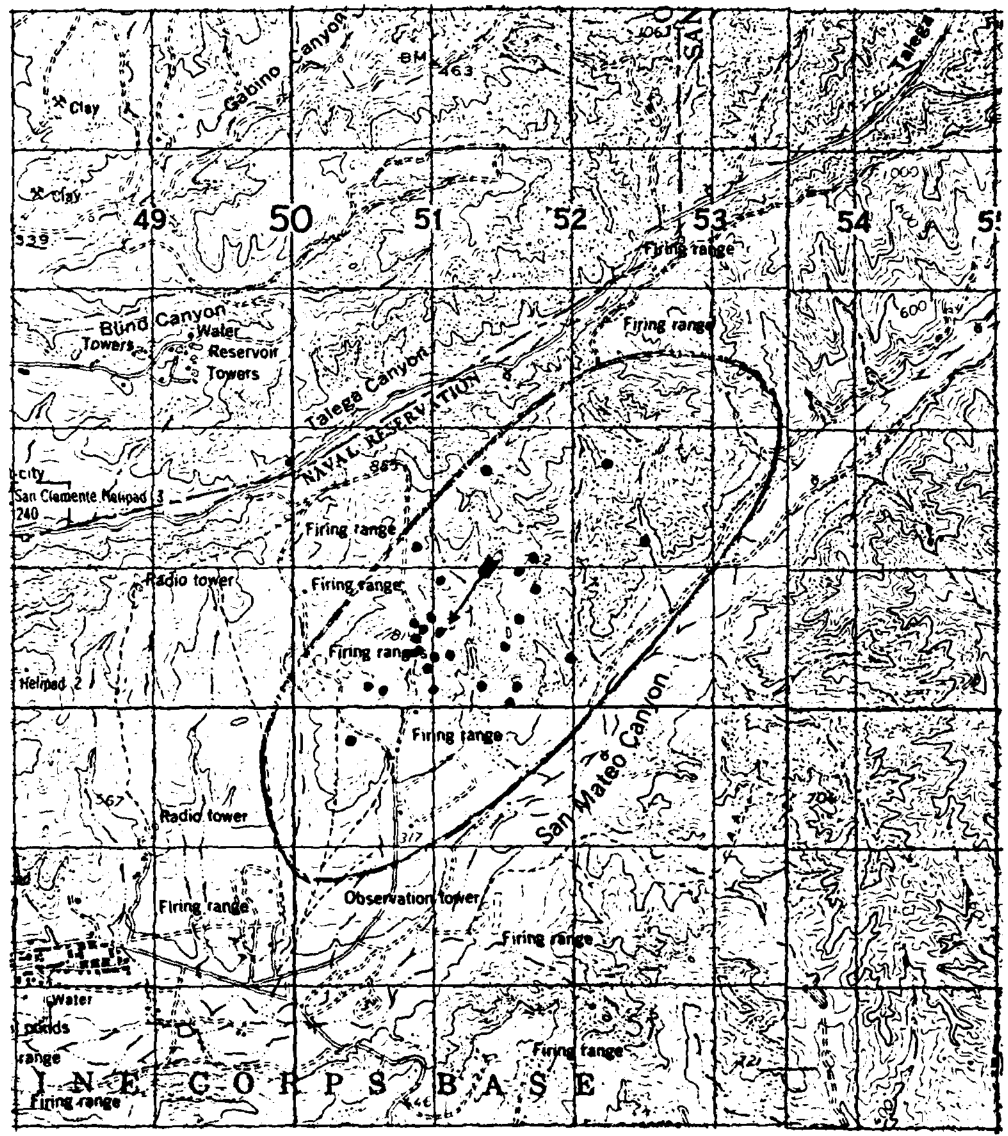
Range: 100 to 1800 meters

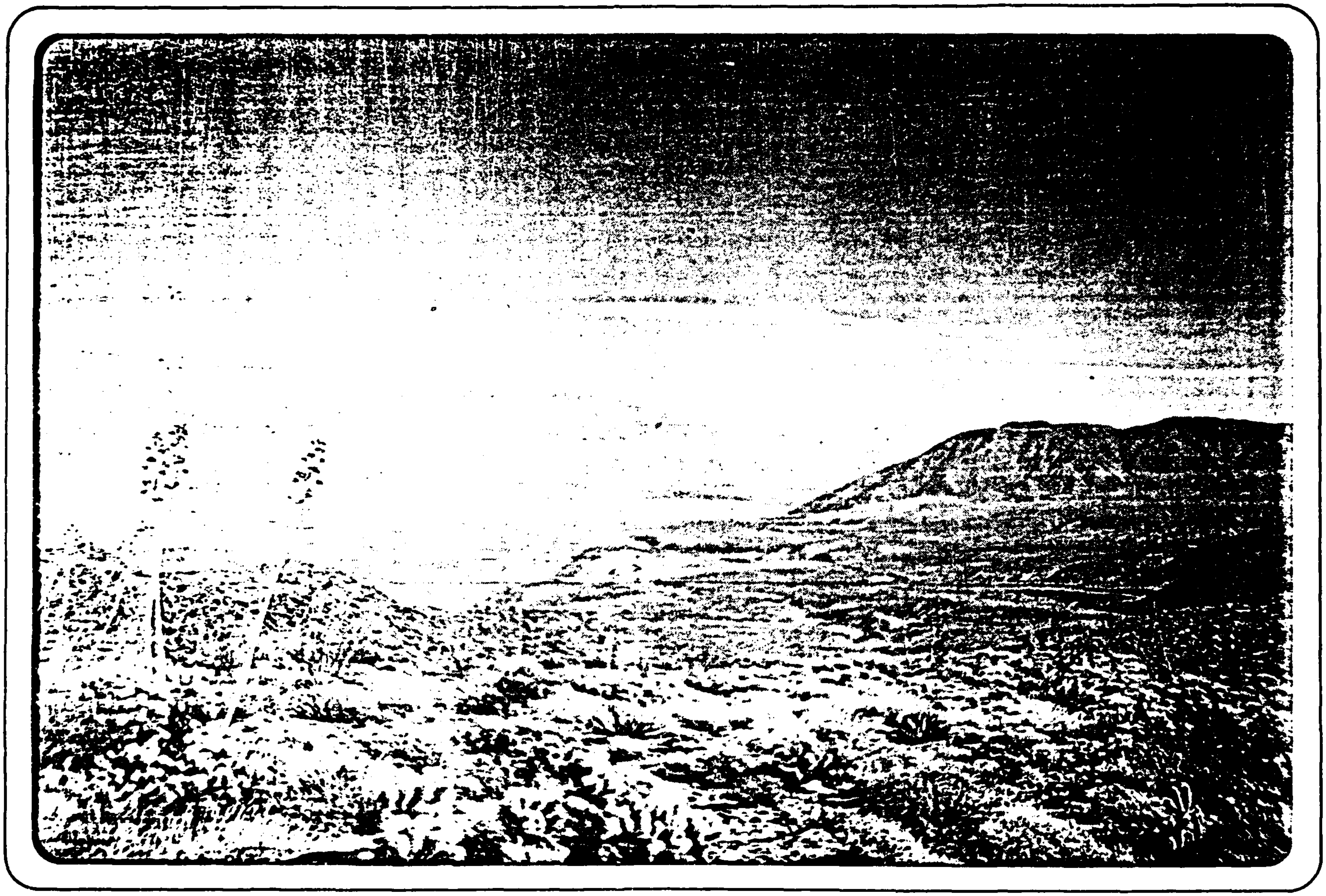
Percent within 100 meters: 7%

500 meters: 54%

1000 meters: 89%

Percent beyond 2000 meters: 0%





Site 8. Clark Lake, California. View to the east.

SITE 8

CLARK LAKE

Contour Interval - 100 feet

READILY IDENTIFIABLE FEATURES

Prominent notch in Coyote Mountain at 120°

Open valleys to the northeast and southeast

Mountains to the northeast and southeast

Location of site on high ground

CONFUSION FACTORS

No cultural features

Other similarly configured points along the ridgeline

ACCURACY OF ORIENTATION (Trial 4)

Average error: 1196m (S.D. 558m)

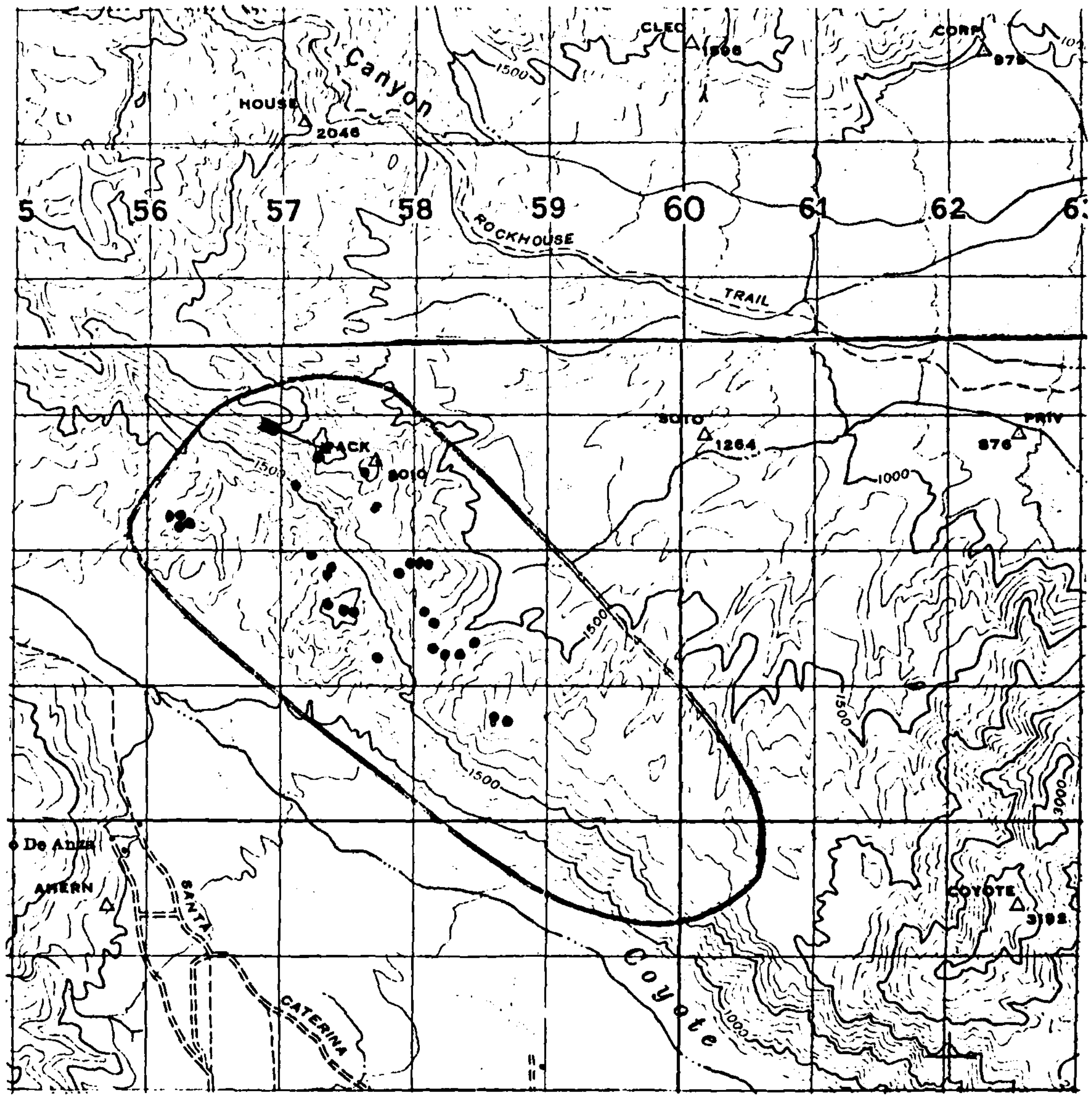
Range: 50 to 2400 meters

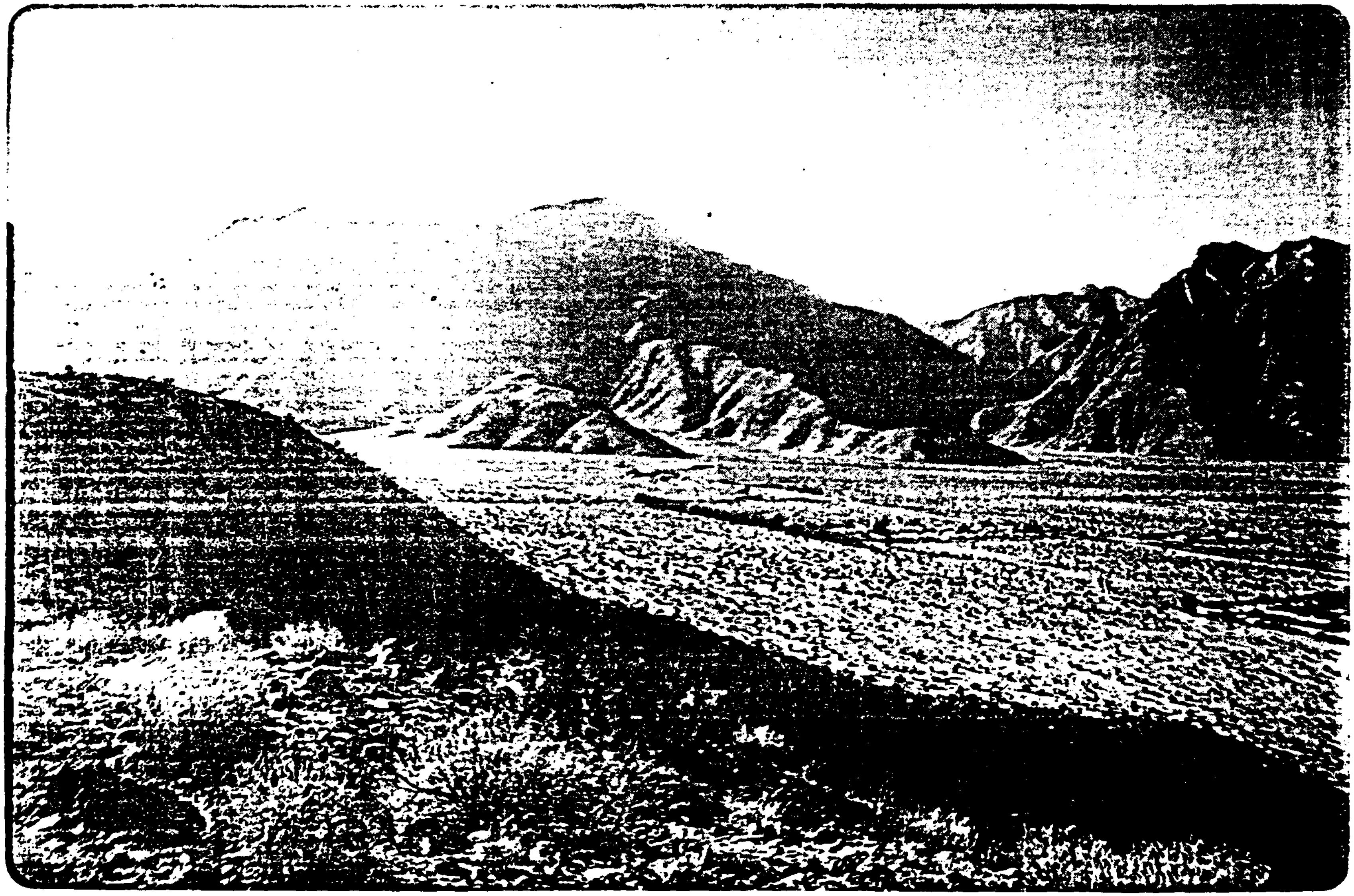
Percent within 100 meters: 4%

500 meters: 11%

1000 meters: 25%

Percent beyond 2000 meters: 7%





Site 9. Berrago Springs, California. View to the northwest.

SITE 9

BERRAGO SPRINGS

Contour Interval - 100 feet to the north of the site and 80 feet to the south of the site.

READILY IDENTIFIABLE FEATURES

Flat valley area to the north of the site

Dramatic rise of mountains to the northwest of the site

Notch in Indian Head Mountain at 320°

Prominent ridges from San Ysidro Mountain at 290° and 300°

Location of the site at an elevated position with a slope upward toward 250°

CONFUSING FACTORS

Construction of new dwelling areas and roadways in the valley

Change in contour interval of abutting map sheets

ACCURACY OF ORIENTATION (Trial 4)

Average error: 1525m (S.D. 1166m)

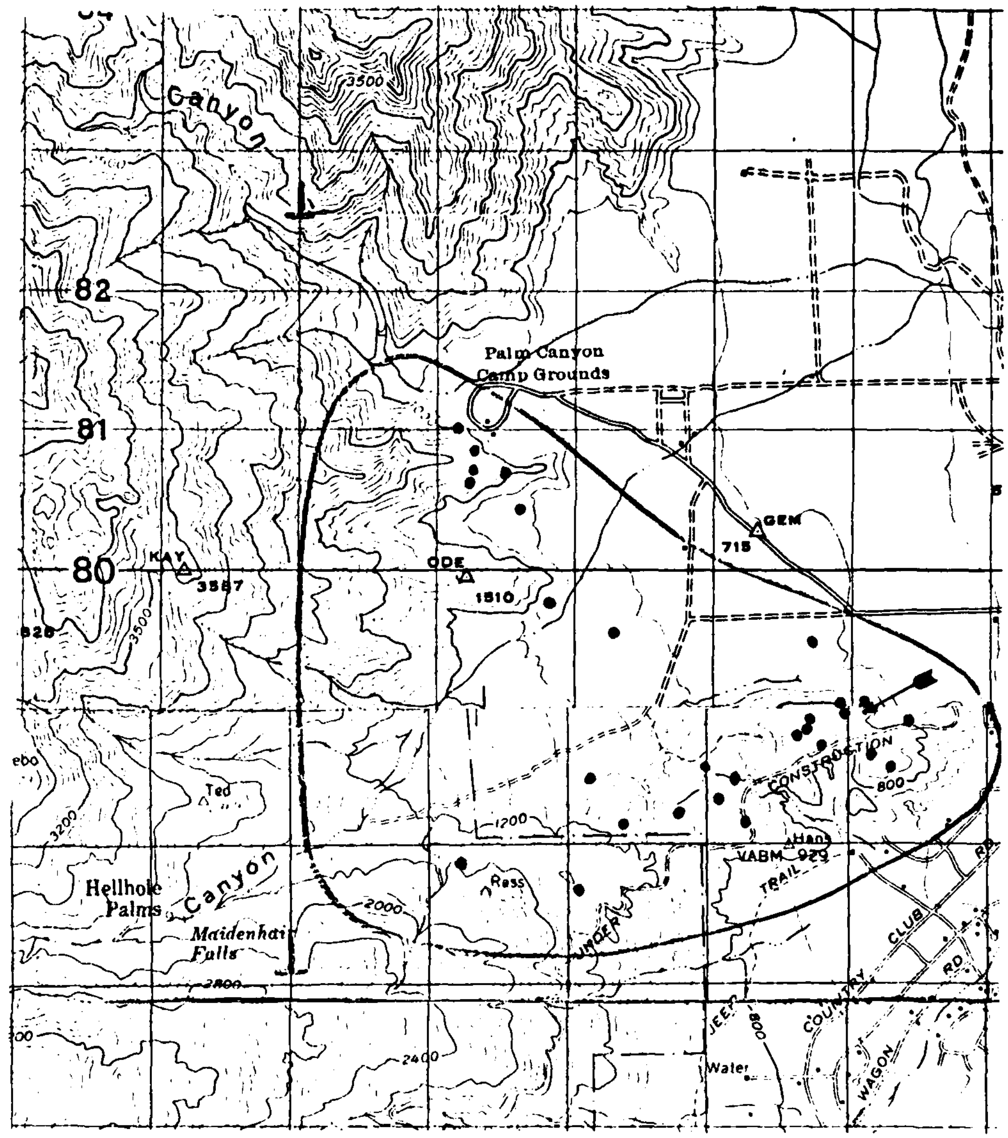
Range: 100 to 3500 meters

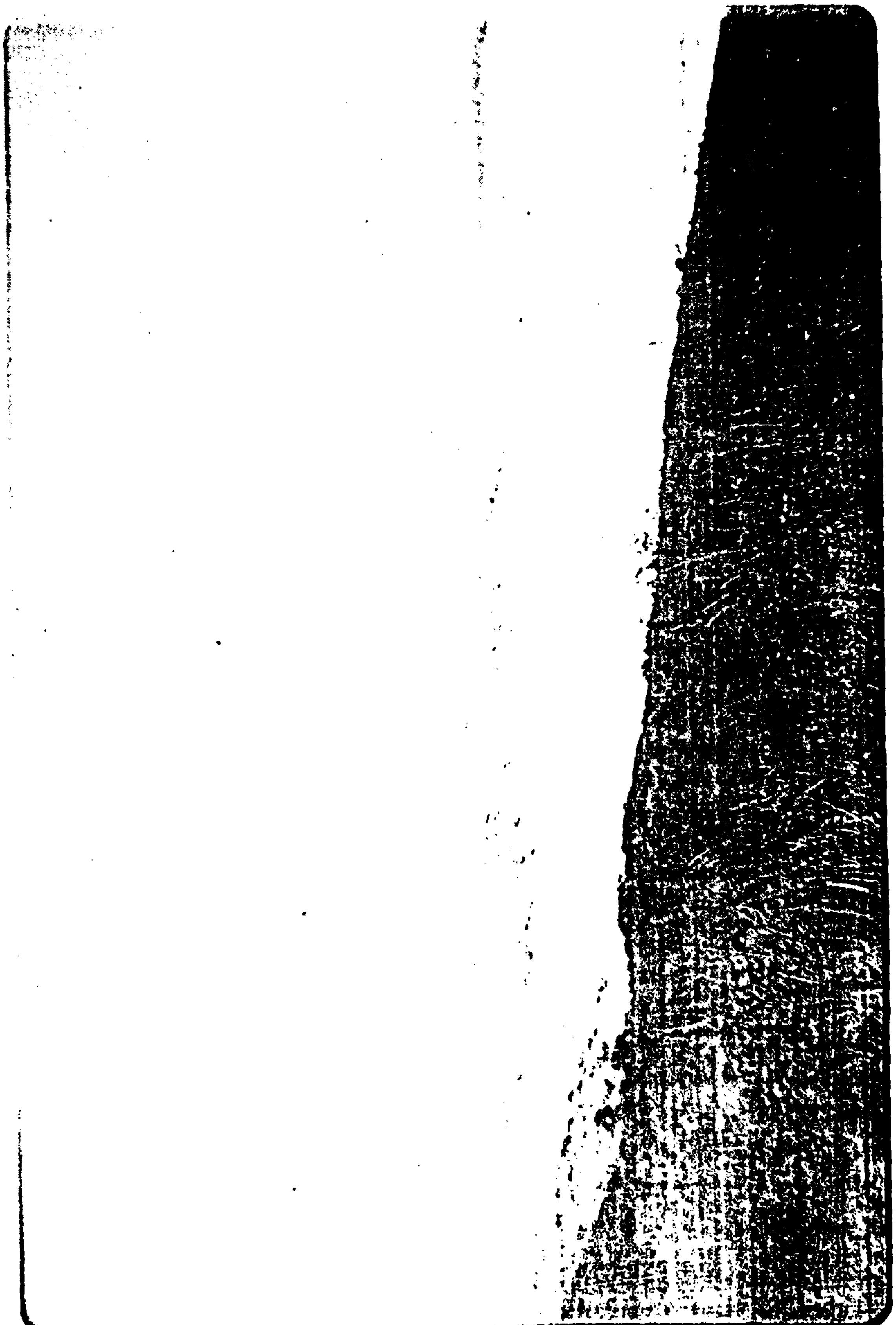
Percent within 100 meters: 4%

500 meters: 32%

1000 meters: 43%

Percent beyond 2000 meters: 36%





Site 10. Cuyamaca, California. View to the southwest.

SITE 10

CUYAMACA

Contour Interval - 80 feet

READILY IDENTIFIABLE FEATURES

Presence of water at 240°

Prominent peaks (North peak, Middle peak, and Stonewall peak) at 275°, 245°, and 210°

Sunrise Highway is visible to the southwest and as it bends away out of sight at 150°

The site is located on top of a ridgeline with higher ground to the north

CONFUSION FACTORS

Cuyamaca reservoir contains only a small amount of water

ACCURACY OF ORIENTATION (Trial 4)

Average error: 2066m (S.D. 1189m)

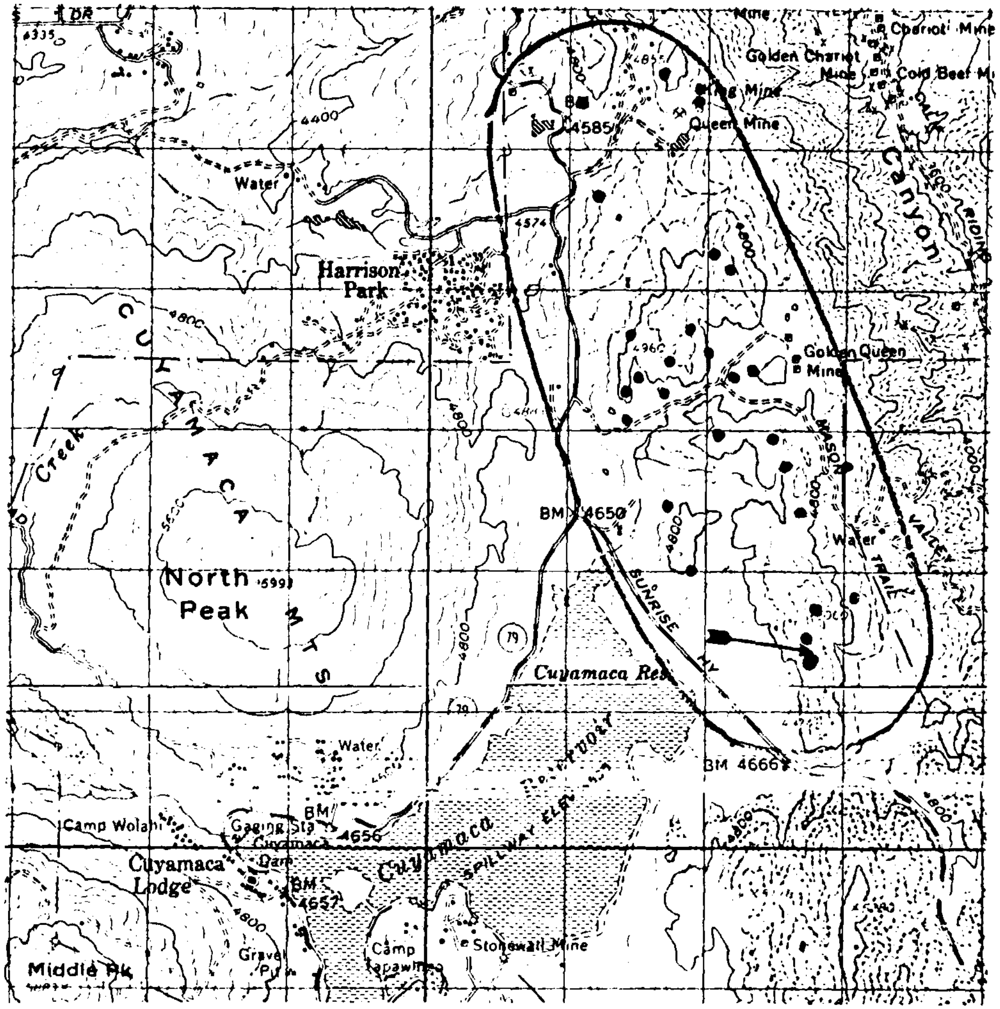
Range: 0 to 4200 meters

Percent within 100 meters: 7%

500 meters: 14%

1000 meters: 18%

Percent beyond 2000 meters: 61%



Site 11. Fort Knox, Kentucky, View to the south.

SITE 11

FORT KNOX

Contour Interval - 20 feet

READILY IDENTIFIABLE FEATURES

Site location on the crest of a hill overlooking a large valley to the east and south

Tip of major landform across the valley at 110°

Small peninsula at 90°

Dirt road coming up the hill from the valley at 230°

CONFUSING FACTORS

Other similar landforms in area

Road adjacent to site not portrayed on the map

Roads portrayed in the valley not visible from the site

ACCURACY OF ORIENTATION (Trial 4)

Average error: 1848m (S.D. 1086m)

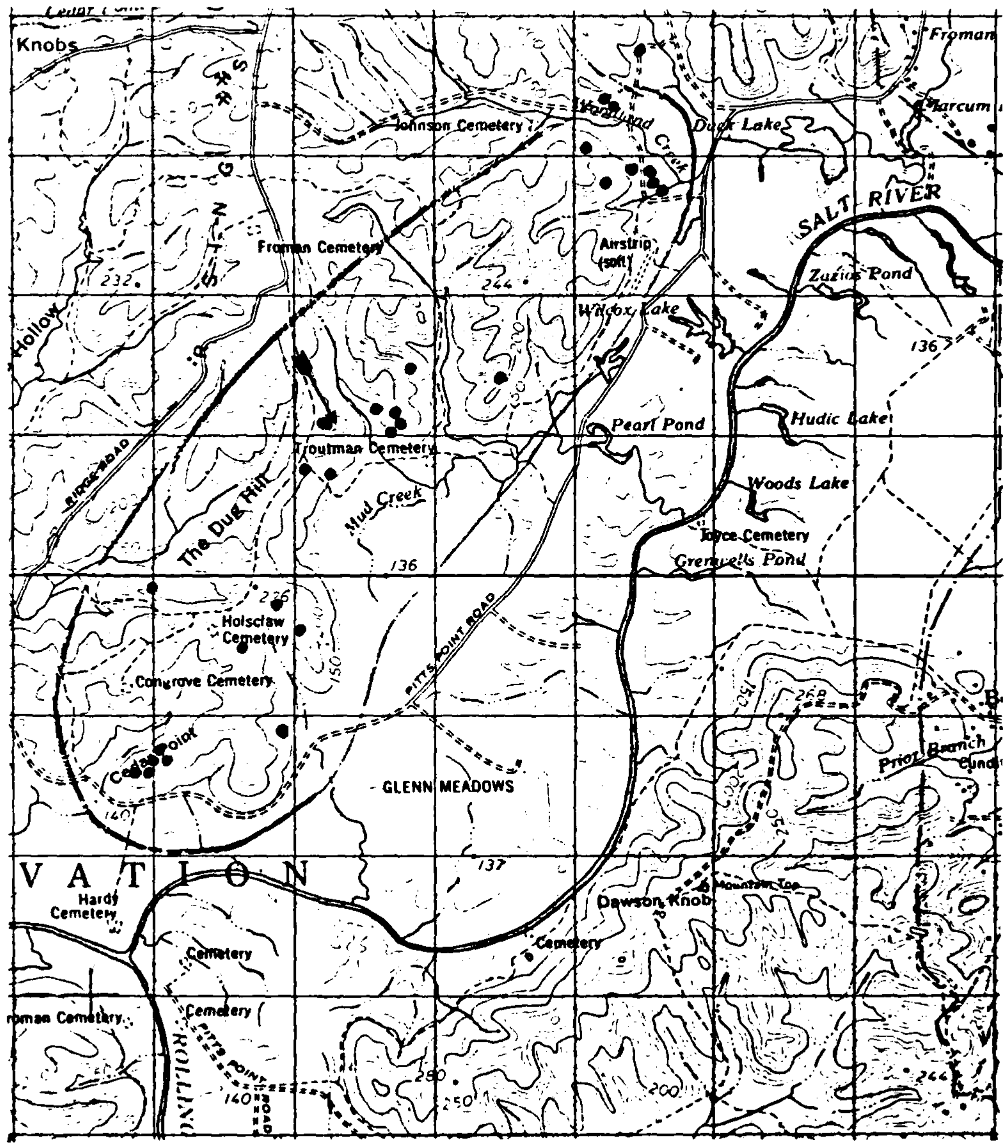
Range: 0 to 3150 meters

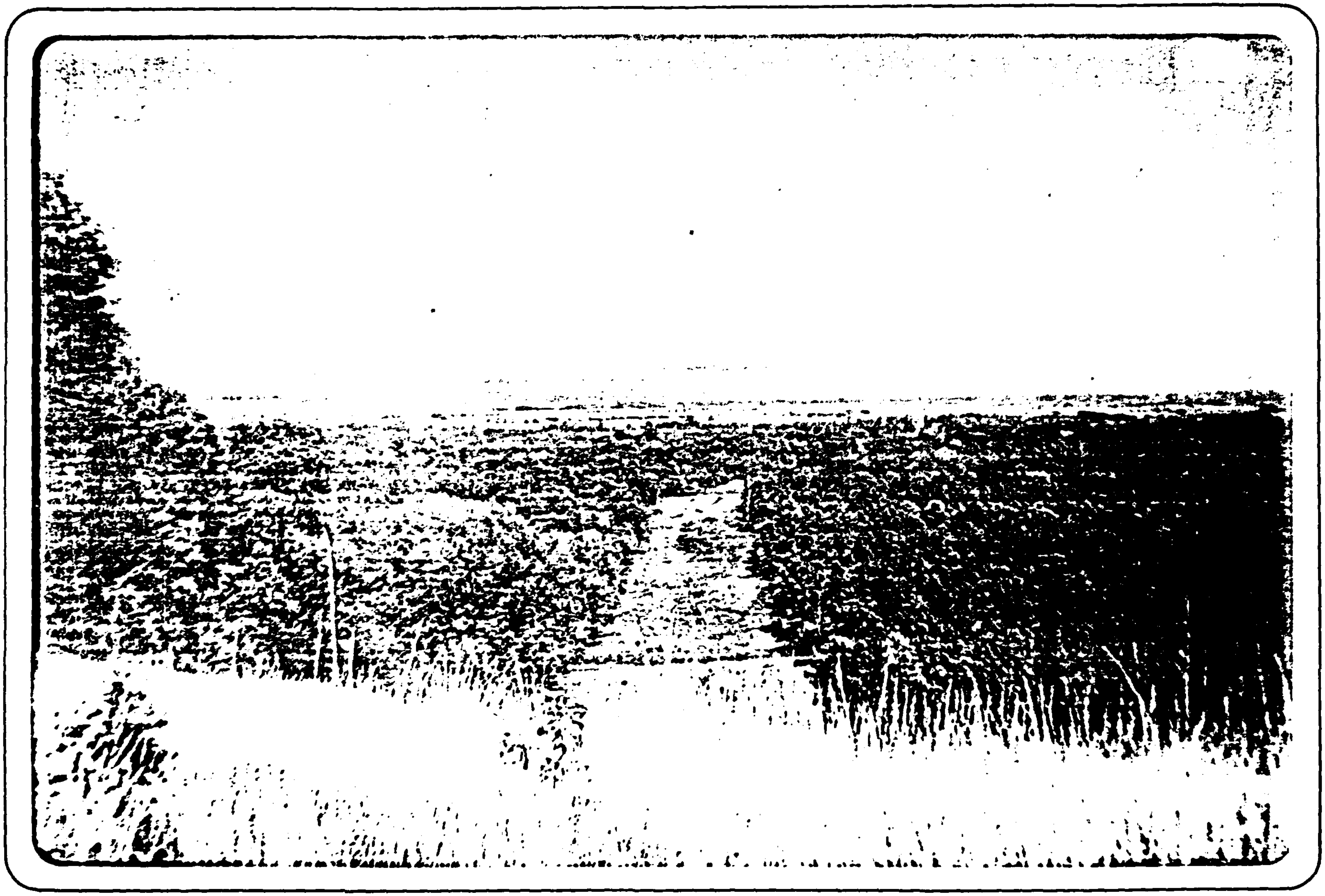
Percent within 100 meters: 4%

500 meters: 25%

1000 meters: 29%

Percent beyond 2000 meters: 54%





Site 12. Fort Knox, Kentucky. View to the northeast.

SITE 12

FORT KNOX

Contour Interval - 20 feet

READILY IDENTIFIABLE FEATURES

Location of site on a steep slope

Vegetation cleared in a strip running at 30° and 210° from the site

Presence of dirt road running northwest from the site

Edge of landforms across the river at 40°

CONFUSION FACTORS

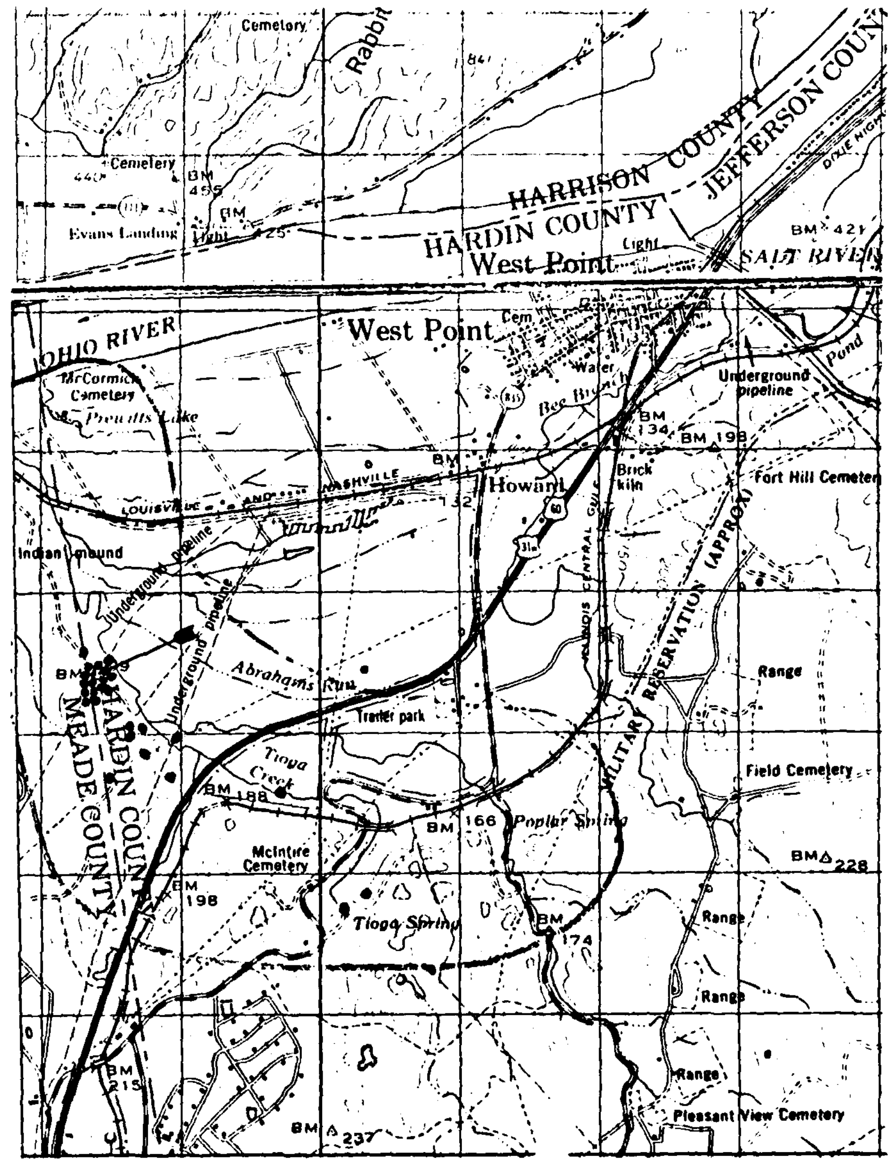
The railways, highways, town and other cultural features portrayed on the map nearby are not visible from the site

ACCURACY OF ORIENTATION (Trial 4)

Average error: 409m (S.D. 665m)

Range: 0 to 2400 meters

Percent within 100 meters:	57%
500 meters:	75%
1000 meters:	89%
Percent beyond 2000 meters:	7%



APPENDIX B

ADDITIONAL DATA ON DISORIENTATION

Before each experimental session, pilots completed a two-part questionnaire. The first part was concerned with the pilots' hours of helicopter flight. The second part of the questionnaire pertained to the pilots' experiences with geographic disorientation and a rating of their ability to interpret terrain relief. These items are reproduced below:

Rate your own ability to interpret terrain relief for orientation:

1	2	3	4	5	6	7	8	9
very poor				average				extremely good

The last time you ever experienced temporary disorientation during NOE flight:

How long did it take to become re-oriented? _________minutes

How far off your planned course were you? _________meters

How did you regain orientation?

_______(a) returned to last known position

_______(b) recognized barrier feature

_______(c) popped up for visual search

_______(d) other (specify) ____________________________

In retrospect, what do you think caused the temporary disorientation? ____

____

Thirty-three pilots completed the questionnaire. Twenty-eight of these pilots subsequently participated in the experiment. The responses are summarized below:

RATING OF OWN ABILITY

Mean rating: 6.56 (S.D. 1.0). Range: 5-9

TIME FOR REORIENTATION

Mean time: 4.8 minutes (S.D. 3.0). Range: 1-15 minutes

DISTANCE OFF PLANNED COURSE

Mean distance: 655 meters (S.D. 485). Range 0-2000 meters

METHOD OF REORIENTATION

Note: Several pilots used more than one method

20 (61%) returned to last known position

12 (36%) recognized a barrier feature

10 (30%) popped up for a visual search

7 (21%) used other methods:

2 (6%) used navigation radios

5 (15%) were able to perform map interpretation and terrain analysis to become re-oriented.

CAUSES OF DISORIENTATION

The responses to this question were predominately one or the other of two types; inattention and inability. Thirteen (39%) of the pilots attributed their temporary loss of orientation to distraction, inattention, or loss of concentration, rather than any lack of skill. Twelve (36%) of the pilots blamed their loss of orientation on their own inability to properly perform map interpretation and terrain analysis, especially when prominent features were unavailable. Another 5 (15%) of the pilots stated that they were attempting to fly "too fast" and their map interpretation "got behind" the aircraft. Two of the pilots (6%) reported that heading errors were the source of their disorientation.